ECONOMIC GEOLOGY

WITH WHICH IS INCORPORATED

THE AMERICAN GEOLOGIST

VOL. VIII JUNE, 1913 No. 4

OCCURRENCE OF COMPLEX AND LITTLE KNOWN SULPHATES AND SULPHARSENATES AS ORE MINERALS IN UTAH.[1]

B. S. BUTLER.

INTRODUCTION.

In studying numerous mining districts of Utah, the writer has found that complex basic ferric sulphates, sulpharsenates, and allied minerals are present in considerable quantities in the oxidized ores of the State, and in some instances are important ore minerals. In the literature of mining geology this class of minerals has been given scant attention, and in the districts where they were seen the writer in no instance found that the character of the minerals had been recognized, though they were commonly known to be metal-bearing, which is, of course, the important feature from the standpoint of the prospector and mine manager. Many mining men, however, as well as mineralogists and geologists, are interested in the mineral composition of ores as well as in their metal content, and occasion is taken to call attention to this type of ore mineral which seems to have been largely overlooked.

PLUMBOJAROSITE.

In 1902 Dr. W. F. Hillebrand and Prof. L. S. Penfield[2] described a new mineral of the jarosite family from Cook's Peak,

[1] Published with permission of the Director of the U. S. Geological Survey.

[2] Hillebrand, W. F., and Penfield, L. S., *Am. Jour. Sci.*, Vol. 14, 1902, p. 213.

N. Mex., to which they gave the name of plumbojarosite. In this mineral lead replaces the potassium of ordinary jarosite, the composition formula being $PbO \cdot 3Fe_2O_3 \cdot 4SO_3 \cdot 6H_2O$.

This mineral was not reported again till 1910, when a second specimen was received by Dr. Hillebrand, which was said to have come from American Fork district, Utah. This was examined chemically and crystallographically by Drs. Hillebrand and Wright[1] and found to agree essentially with that previously described from New Mexico.

Long previous to the recognition of the mineral in 1902, Dr. Hillebrand[2] had made an analysis of a ferric sulphate from Leadville, Colo., that from its close correspondence to the analyses of plumbojarosite, as shown in the accompanying table, gives strong reason to suspect that it was that mineral rather than a mixture of minerals, as was then thought. Other ferric sulphates from Leadville were analyzed that contained notable amounts of potassium and lead, and may have been mixtures of jarosite and plumbojarosite.

In 1911 the writer and Dr. W. T. Schaller[3] described the occurrence of plumbojarosite from six localities in Beaver County, Utah. In some of these occurrences the mineral was present in sufficient quantity to be a lead ore of some importance. It became evident that the mineral is not a mineralogical curiosity of rare occurrence, but an ore mineral.

Since studying the occurrence of plumbojarosite in Beaver County, the writer has visited numerous other camps in Utah and has found that plumbojarosite is of widespread occurrence, being collected from no less than 18 localities, including those mentioned above. In some of these occurrences it is present in considerable quantity and, while not of high grade, is a commercial ore mineral.

Physical Properties.—Plumbojarosite, as seen in different hand samples, varies considerably in appearance. In color it ranges from a rather light, nearly ocher yellow, to a rather dark brown.

[1] Hillebrand, W. F., and Wright, F. E., *Am. Jour. Sci.*, Vol. 30, 1910, p. 191.
[2] "Geology and Mining Industry of Leadville, Colo.," 1886, p. 606.
[3] Butler, B. S., and Schaller, W. T., *Am. Jour. Sci.*, Vol. 32, 1911, p. 422.

When relatively coarsely crystalline it has a distinctly micaceous appearance, but in the very finely crystalline material it appears earthy except on close examination. Where massive it frequently has a distinctly schistose structure.

The mineral has apparently been commonly mistaken for hydrated iron oxides, and it has been assumed that the metal

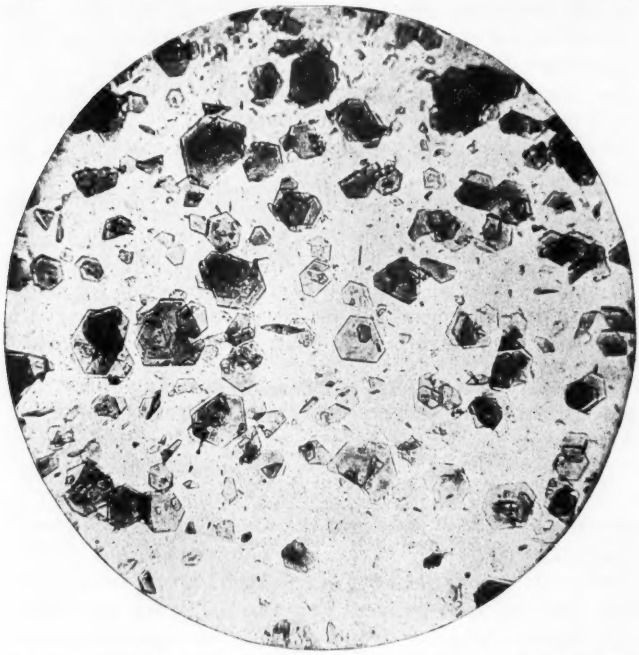

FIG. 26. Plumbojarosite, Moskow Mine, Beaver County, Utah. Magnified 45 times.

values were present as carbonates or "chlorides" mixed with the hydrated iron oxide.

It is usually not difficult to distinguish between the hydrated iron oxides and the basic sulphates, since the oxides have a harsh

gritty feel when rubbed between the fingers, while the basic sulphates, due to their micaceous character, have a smooth oily feel. The luster of the two is also usually distinctive, the sulphate having a silky luster while the oxide is earthy. In the very fine material this character is less distinctive.

Under the microscope the crystals in every instance are seen to be thin hexagonal plates of a light golden-yellow color. The crystals vary greatly in size in different occurrences and in a single occurrence, but rarely exceed 0.25 millimeter in width. In all the material examined microscopically the crystals are uniaxial, optically negative with strong birefringence. The accompanying microphotograph, Fig. 26, shows the general character of the crystals.

Chemical Composition.—Three analyses of plumbojarosite have been made, two from Utah and one from New Mexico. These are given in the following table together with an analysis of oxidized material from Leadville, Colo., which is not known to be a definite mineral and the composition of the mineral is calculated from the chemical formula $PbO \cdot 3Fe_2O_3 \cdot 4SO_3 \cdot 6H_2O$.

ANALYSES OF PLUMBOJAROSITE.

	Beaver Co., Utah.	Cook's Peak, N. Mex.	American Fork, Utah.	Calculated.	Oxidized Material from Lower Waterloo Mine under Gray Porphyry, Leadville.
Fe_2O_3	42.11	42.37	42.87	42.38	44.40
PbO	18.32	19.84	18.46	19.74	19.50
K_2O	0.13	0.17	0.15	.....	.15
Na_2O		0.21	0.52	.....	.37
SO_3	27.59	27.06	27.67	28.33	25.07
H_2O	9.16	9.56	10.14	9.55	8.99
CuO	.....	0.27	0.10	.....	.....
CaO	0.00	0.05	0.06	.....	.....
Insol	2.64	0.51	0.40	.....	.....
ZnO	0.30	.....	.....	.....	.....
SiO_2	.....	.....	.....	.....	.36
Al_2O_3	.....	.....	.....	.....	.23
As_2O_3	.....	.....	.....	.....	.39
P_2O_5	.....	.....	.....	.....	.11
Cl	.....	.....	.....	.....	.04
	100.25	100.15	100.37	100.00	99.61
Density	3.60	3.665	.....	.....	.....
Lead	.....	.....	.....	18.31	.....
Iron	.....	.....	.....	29.66	.....

The analyses show a close agreement among themselves as well as with the calculated values.

OCCURRENCES OF PLUMBOJAROSITE IN UTAH.

The first occurrence described from the state, as already noted, was from the American Fork district. No data are available, however, to show the field relation of the specimen analyzed from that district.

In Beaver County the mineral was recognized in the ores from the following mines and prospects: Horn Silver, Hub, Moscow, Red Warrior, Harrington-Hickory and an unnamed prospect pit, and probably is present in other deposits of this section. In these occurrences the mineral is secondary, resulting from the oxidation of mixed sulphide ores. In the Red Warrior and Moscow mines, at the time of visit, it was present in sufficient amount to be characterized as a commercal ore mineral though by no means as important as the carbonate, cerusite.

In the Marysvale district, Piute County, the mineral was found on the dump of the Deertrail mine. In the specimen collected the plumbojarosite surrounded a core of galena. It was not observed in the mine but evidently resulted from the oxidation of lead and iron sulphides. Jarosite was also observed in considerable abundance in this mine.

In the Clifton district, Tooele County, the mineral occurs in the Gold Hill mine of the Western Utah Copper Co. At this locality it was observed in considerable abundance, especially in an oxidized lead ore body on the 300-foot tunnel level. Owing to lack of cheap transportation facilities, there has been little production from these ores. With better transportation they would doubtless be of commercial grade.

In the Fish Springs district plumbojarosite was observed in considerable quantity in parts of the Utah mine, where it has formed in the oxidation of lead and iron sulphides. It is said that "second class" oxidized ore in some instances forms a casing around the high grade ore. This second grade is in part plumbojarosite. Under present transportation conditions the second

grade ore cannot be profitably handled, but with cheap transportation facilities it would be of commercial grade.

Plumbojarosite was also observed on the dump of the Galena mine west of the Utah mine. The mine was closed at the time of visit, but the occurrence is said to be similar to that in the Utah mine.

The mineral was collected from a vein in quartzite in the north end of the Dugway Range.

Plumbojarosite was collected from the dump of the Tacoma mine in the Lucin district, Boxelder County, and from a prospect tunnel on the property of the Mineral Mountain Mining Co.

In the Ophir district, Tooele County, it was found on the dump of the upper workings of the Cliff mine and from the dump of the Chloride Point and East Side tunnel workings in the Lion Hill section.

In the Stockton district it was collected from the ore bins of the upper tunnel on the Honorine vein and from the dump of the Ben Harrison mine.

BEAVERITE.

The mineral beaverite was first described from the Horn Silver mine, Beaver County,[1] where it occurs in the oxidized ores resulting from the alteration of an ore body composed principally of sulphides of lead, iron, zinc and copper.

Physical Properties.—The mineral is a canary-yellow earthy looking material that can usually be easily crushed in the fingers. Under the high power of the microscope the material is seen to be crystallized in distinct hexagonal plates. These are too small for accurate measurement of the crystal angles or determination of the optical character. The refractive index of the light ray vibrating perpendicular to the plates is about 1.80.

Almost every crystal contains a minute inclusion whose character has not been determined. The material analyzed appeared under the microscope to be very pure except for these inclusions,

[1] Butler, B. S., and Schaller, W. T., "Some Minerals from Beaver County, Utah," *Am. Jour. Sci.*, Vol. 32, 1911, p. 418.

and it is probable that the silica that appears in the analysis is due to them.

Chemical Composition.[1]—The mineral is soluble in boiling hydrochloric acid, leaving the insoluble matter, chiefly silica, behind. On cooling, lead chloride separates out in considerable amount. The lead reaction can also readily be obtained with sodium carbonate on charcoal. On adding ammonia in excess to the hydrochloric acid solution, the ferric iron is thrown down as a voluminous brown precipitate, and the solution has the deep blue color indicative of copper. By the quantitative determination, the presence of a small amount of alumina was established. The insoluble matter consists mostly of silica, only a slight residue remaining after treatment with hydrofluoric acid.

The following table shows the chemical analysis of the mineral together with the calculated analysis from the formula $CuO \cdot PbO \cdot Fe_2O_3 \cdot 2SO_3 \cdot 4H_2O$.

ANALYSIS AND RATIOS OF BEAVERITE.

Insol.	10.05			
CuO	9.70	.121		.92 or 1
PbO	29.44	.132		1.00 or 1
Fe_2O_3	17.28	.108	.144	1.07 or 1
Al_2O_3	3.64	.036		
SO_3	21.32	.266		2.01 or 2
H_2O	9.02	.501		3.80 or 4 (= 4x .95).
	100.45			

The ratios agree well with the formula

$$CuO \cdot PbO \cdot FE_2O_3 \cdot 2SO_3 \cdot 4H_2O,$$

in which the copper and lead are assumed to be present in equal molecular amounts, and in which a little ferric iron is replaced by alumina.

A comparison of the analysis with the insoluble matter deducted and reduced to 100 per cent., with the values calculated for the formula last given, is shown below.

[1] The material was examined chemically by Dr. W T. Schaller.

COMPARISON OF ANALYSIS WITH CALCULATED VALUES.

	Analysis.	Calculated.
CuO	10.74	11.70
PbO	32.50	32.80
Fe_2O_3	19.13	17.61
Al_2O_3	4.03	3.75
SO_3	23.60	23.54
H_2O	10.00	10.60
	100.00	100.00

Copper	9.34
Lead	30.44
Iron	12.33

A mineral of similar composition and character occurs in considerable amount in the oxidized ores of the Alta Consolidated mine in the Alta district. At the time of visit ore that contained this mineral as an important constituent was being taken out for shipment.

A mineral corresponding to beaverite in physical and chemical properties was collected from the dumps of the Hidden Treasure mine, Ophir district, and from the Paymaster mine in the Beaver Dam Mountains, Washington County.

BEUDANTITE AND ALLIED MINERALS.

Under the name beudantite are included a series of minerals of somewhat variable and uncertain composition, but essentially sulpharsenates or sulphphosphates of lead and ferric iron with minor quantities of other constituents, especially copper, which may reach several per cent.

The arsenates have been commonly called beudantite, while the phosphates have been designated corkite, though this division does not appear to have been followed by all writers.

So far as the writer is aware, the first locality on this continent from which a member of this series was described, was from Beaver County, Utah.[1] In Beaver County, the mineral corkite occurs in the Harrington-Hickory and Wild Bill mines in the Star district and probably in other mines of that region.

The mineral as seen in the hand specimen is a light green earthy

[1] *Op. cit.*, p. 423.

looking material which when crushed in the fingers has a gritty feel like fine sand. Under the microscope it is found to be well crystallized, the larger crystals being 0.15 millimeter in diameter. The crystals are golden yellow in color and have the general appearance of being a combination of the cube and octahedron. They are rather strongly birefringent, however, and are probably hexagonal rhombohedral.

Corkite is readily soluble in boiling hydrochloric acid from which solution lead chloride separates out in quantity on cooling. The solution contains, besides lead, abundant ferric iron and the sulphate and phosphate radicals. Qualitative tests failed to show the presence of any arsenic, and only a mere trace of copper is present in the corkite from these mines. Heated in a closed tube, the mineral darkens and gives off water.

In both of the mines mentioned the original ores were a replacement of limestone near an intrusive rock and considerable apatite and contact silicates were formed with the metallic sulphides, mainly pyrite, galena, sphalerite, and chalcopyrite. The corkite is a secondary mineral resulting from the alteration of these ores, the phosphate doubtless being derived from the apatite and the metallic content from the sulphides.

A mineral having physical properties similar to those mentioned above but containing mainly arsenic in place of phosphate, was collected from several prospects near the south end of Clifton Mountain in the Clifton district, Tooele County. The ores occur as replacement veins in limestone. The beudantite is an oxidation product and since the mines have been but slightly developed, the primary minerals from which it was derived are not known though it is safe to infer that arsenides or sulpharsenides were present. Similar minerals were collected from the Black Warrior and Paymaster mines, Washington County. There can be little doubt that minerals of this type are present in many other mines of the state.

Numerous complex arsenates occur in the Tintic[1] district, but those do not contain ferric iron as an important constituent.

[1] Tower, G. W., and Smith, G. O., Nineteenth Ann. Rept. U. S. Geol. Survey, Pt. 3, p. 691.

JAROSITE.

Jarosite, $K_2O \cdot 3Fe_2O_3 \cdot 4SO_3 \cdot 6H_2O$, is present in many of the mines of the state and in several has been noted in abundance. It has been previously described from the Tintic district,[1] and from the Mercur district.[2]

The writer has noted the mineral in particular abundance in the Deertrail mine in the Marysvale district where it is closely associated with sericitic muscovite, from the Dixie copper mine in Washington County, from a prospect in the Detroit district where it has been mined to a limited extent for flux in a local smelter, and from several mines in Beaver County. It is also present with allied minerals, such as plumbojarosite in other localities. In fact these two minerals, jarosite and plumbojarosite, can be readily detected only by chemical means. There is no doubt that it is one of the rather common minerals in the ores of the state.

Utahite, $3Fe_2O_3 \cdot 3SO_3 \cdot 4H_2O$, occurs in the Tintic district,[3] and is probably present in other districts.

It rather closely resembles jarosite in its physical properties. In the material that the writer has collected he has not found utahite and consequently is inclined to consider it of less frequent occurrence than jarosite.

It is frequently not possible to collect these minerals in sufficient purity to permit of a careful chemical determination, and there is little doubt that there are numerous minerals allied to these in composition in the ores of the state.

In the lower portion of the oxidized "capping" of the Bingham disseminated copper ores, a mineral or minerals occur that are similar in many physical properties to beaverite. This could not be separated in sufficient purity to permit of careful chemical examination, but it gives a strong reaction for sulphate and ferric iron and some of the material tested contained copper in notable amounts, and since no other copper mineral was recognized this mineral is believed to be copper bearing. It contained no lead.

[1] *Op. cit.*, p. 702.

[2] Spurr, J. E., "Economic Geology of the Mercur Mining District, Utah," Sixteenth Ann. Rept. U. S. Geol. Survey, Pt. 2, p. 440.

[3] Nineteenth Ann. Rept. U. S. Geol. Survey, Pt. 3, p. 703.

Other material similar in appearance showed no copper, or but a trace.

OCCURRENCE OF THE COMPLEX FERRIC SULPHATES AND ARSENATES.

All the minerals described occur in the oxidized portion of the veins. They are not present in the outcrop, though they have been found only a short distance below the surface. They have resulted from the oxidation of mixed sulphide and arsenide ores and in some instances appear to occupy essentially the position of the primary ores; in other instances the occurrence suggests the formation of the minerals by the action of ferric solutions on sulphides or other minerals, examples being cores of galena enclosed in plumbojarosite and jarosite occurring with sericitic muscovite where the potassium appears to have been derived from the muscovite.

As already noted, the minerals are not stable under surface conditions, and there can be no doubt that they are less stable than the less complex carbonates and oxides and that they break down to form these minerals. In fact numerous examples have been observed where the minerals were altering to hydrous iron oxide, and probably to carbonates of lead, etc., though the metals other than iron in some instances at least seem to have been removed when the mineral broke down.

It is evident, therefore, that these relatively complex compounds represent a stage in the process of oxidation between the sulphides and the more simple oxide and carbonate compounds. The simpler sulphates, as anglesite, are doubtless formed to some extent in the alteration of these minerals, though all the metallic sulphates are relatively unstable. For example, anglesite commonly occurs as an intermediate stage in the alteration of galena to cerusite,[1] and linarite has been noted in a similar relation to more complex sulphide ores in the Horn Silver mine, Beaver County, and brochanthite also occurs as an intermediate stage in the alteration of covellite and chalcocite to carbonates.

[1] Boutwell, J. M., "Geology and Ore Deposits of the Park City District, Utah," Prof. Paper U. S. Geol. Survey No. 77, p. 114.

In the breaking down of the complex ferric sulphates, hydrous iron oxides and soluble or insoluble sulphates may be formed, or sulphuric acid may be liberated that will act on other minerals to form sulphates.

It is apparent that the formation of the complex ferric sulphates simply delays the oxidation process while they are passing from the zone in which they were formed and are stable to a zone where they become unstable and break down.

The ferric sulphates and arsenates have been observed most frequently in the relatively arid regions which suggests that an arid climate may be especially favorable to the formation of such minerals. Their presence in considerable abundance in the Alta district, which has a large rainfall, and possibly at Leadville, Colo., throws serious doubt on this suggestion and more observations are necessary before a generalization concerning the conditions under which they form will be warranted.

One generalization is, however, warranted, namely, that all yellow and brown more or less earthy materials are not limonite, and if such contain metals other than iron they are not necessarily present as carbonates or "chlorides."

The geologist or mineralogist visiting a mine for a few days is not likely to get the best mineral specimen that the mine affords, but if those in charge of the mine operations will preserve such material and turn it over to someone interested in the mineralogy of ores, we may soon have much more data concerning these interesting types of minerals, which in the mines of Utah, at least, are much more important than is generally recognized.

A MAGMATIC SULPHIDE ORE BODY AT ELKHORN, MONTANA.[1]

ADOLPH KNOPF.

INTRODUCTION.

Elkhorn is situated in the Elkhorn mountains, 33 miles northeast of Butte, Montana. The areal geology of the environs of Elkhorn and the economic geology of the Elkhorn mine, the largest producer in the district, are described in the report on the Elkhorn mining district by Walter Harvey Weed.[2] At the time of Weed's examination the existence of the ore body described in this paper was not known.

Geologically, Elkhorn lies on the eastern margin of the great quartz monzonite intrusion, known as the Boulder batholith, just as Butte lies on the western margin. A large number of ore deposits are genetically associated with this batholith and are commonly grouped along its margin or in parts of the roof that yet remain within its central portion. A special feature of these deposits is that they are accompanied at a number of localities by a notable development of pneumatolytic minerals, among which tourmaline is exceedingly common. There are within the general area of the batholith still later ore deposits which are of post-Miocene age, but which are not genetically referable with certainty to any igneous rocks. These, as well as the older deposits, show intense hydrothermal metamorphism of their wall rocks, and this universal prevalence of wall rock alteration is a feature of great importance in the comparative study of the ore body here described.

[1] Published with the permission of the Director of the U. S. Geological Survey.

[2] Weed, W. H., "Geology and Ore Deposits of the Elkhorn Mining District, Jefferson County, Montana, with an Appendix on the Microscopical Petrography of the District by Joseph Barrell," Twenty-second Ann. Rept. U. S. Geol. Survey, Pt. 2, 1901, pp. 399–549.

At Elkhorn the quartz monzonite has invaded Paleozoic limestones and shales overlain by Mesozoic sandstones and shales, which in turn are overlain by a stratiform series of andesite flows and breccias. The intruded rocks have all been considerably thermometamorphosed, but in places pneumatolytic metamorphism has ensued, characterized locally by the development of tourmaline and axinite. In places along the contact there has been much ferration, as shown by the development of bodies of magnetite intergrown with andradite and axinite.

ORE DEPOSITS AT ELKHORN.

A considerable variety of ore deposits is found within the Elkhorn district—an area of approximately ten square miles. Several genetically distinct types are included: the magmatic sulphide ore body at the Golden Curry mine, the auriferous contact-metamorphic lode at the Dolcoath mine, the contact-metamorphic bodies of magnetite ore north of Elkhorn Peak, the tourmaline-bearing galena-quartz ore at the Queen mine, and the lead-silver replacement deposit at the Elkhorn mine. These types are very briefly characterized here in order to set forth the metallogenetic environment of the ore body that is the subject of this paper.

The ore body at the Dolcoath mine is a stratum 12 to 18 inches thick, composed essentially of garnet (andradite), diopside, calcite, and epidote. The ore is commonly of dense, massive texture, but in proportion as the amount of calcite increases, the garnet and epidote shows more complete crystallographic development. Sulphide and telluride of bismuth carrying gold, together with chalcopyrite, constitute the ore minerals and occur in small amount, intergrown both with the silicates and the calcite. That the garnetization and the recrystallization of the calcite took place nearly simultaneously is proved by the fact that perfect crystals of garnet occur completely isolated in the midst of large crystalline patches of calcite.

On the north side of Elkhorn Peak are found bodies of iron ore near the contact of a large limestone stratum and the underlying andesite. The iron ore consists principally of magnetite

associated with andradite. It has been mined to some extent as a flux. The magnetite is mainly intergrown with the garnet, but is also present as thin strings and quartz-magnetite veinlets traversing the garnet rock. The garnet, as determined by the immersion method, has a refractive index considerably higher than 1.79, which indicates that it is of andraditic composition. Axinite in coarse-bladed masses up to a fist in size is found locally; some of this encloses euhedral crystals of garnet. Other minerals occurring in the ore bodies in lesser amounts are specular hematite, pyrite, chalcopyrite, and epidote. The deposits are extensively oxidized and much soft iron oxide, in part derived from the andradite, is present.

The ore body at the Queen mine is the only representative in the Elkhorn area of the tourmaline types of deposits, which are so abundant in the surrounding region.[1] The ore is an argentiferous galena-quartz carrying tourmaline. It is of interest to note that arsenopyrite, which is a common associate of tourmaline the world over, occurs in this deposit, but is found nowhere else in the Elkhorn area.

The premier ore deposit of the district has been that of the Elkhorn mine, and the report on the Elkhorn district, as Weed himself points out, is essentially a report on the Elkhorn mine. By 1900 the mine had produced 8,902,000 ounces of silver, 8,500 ounces of gold, and 4,000,000 pounds of lead. The ore body consists essentially of argentiferous lead ore replacing dolomite beneath the arches of a hanging wall of hornstone. One of the most interesting features of the Elkhorn deposit in comparison with the other deposits of the district is the almost complete absence of metasomatic gangue minerals. The other deposits show such characteristic minerals as andradite, diopside, epidote, axinite, and tourmaline—all indicative of origin at high temperatures. The most productive ore body of the district, however, is devoid of any evidence that it was formed under conditions of high temperature.

[1] Knopf, Adolph, "Ore Deposits of the Helena Mining Region, Montana," Bull. U. S. Geol. Survey, No. 527, 1913.

GOLDEN CURRY MINE.

General Features.—The Golden Curry, or Jacquemin mine, as it is shown on the map of Elkhorn accompanying Weed's report, is located near the intrusive contact of the quartz monzonite and a series of thin-bedded argillaceous limestones to which Weed gave the name Starmount limestone. The limestones have been highly metamorphosed into dense-grained intergrowths of various lime-silicates forming a series of dark-colored banded hornstones which preserve the original sedimentary stratification. Heavy garnet rocks have been produced locally and the garnet (probably andradite) is in places coarsely crystalline, especially near patches of calcite; where the calcite has been partly leached out by weathering, a porous rock is produced which shows druses lined with crystalline garnet. Some of the garnet rock contains a little intergrown chalcopyrite and is said to constitute ore. Above the main pit of the mine are considerable amounts of a somewhat notable rock composed of garnet and opal. Some of it consists of garnets set in a matrix of conchoidally fracturing opal of light yellowish color. Under the microscope a specimen of the garnet-opal rock was found to consist of garnet, diopside, calcite, opal, and cryptocrystalline silica, in part spherulitic. The evidence seems to indicate that the garnet had been fractured, crushed, and recemented by opal and cryptocrystalline silica.

The main working of the mine consists of a large open pit from which 50,000 tons of iron ore have been mined, mainly as a flux, for the smelters. The ore averaged 40 per cent. iron and carried from four to five dollars a ton in gold. The pit is located at the immediate contact of the contact-metamorphic rocks and the granite, and the ore is mainly magnetite, which forms veins in the granite itself, the veins attaining a thickness up to three feet. In some of the underground workings beneath the main pit, namely, in tunnel No. 1, there are some lodes of heavy red jasper-like material which chemical analysis shows to be a hydrous ferric silicate.

PARTIAL ANALYSIS OF IRON ORE.

J. G. Fairchild, analyst.

Fe_2O_3	59.23
SiO_2	31.37
H_2O (loss on ign.)	8.40
	99.30

This material is also mined as iron ore. It contains considerable martite, and rarely some pyrite. The analysis above, however, represents only the homogeneous portion showing conchoidal fracture.

In a raise above this lower tunnel a large chamber of ore inclosed in granite has been stoped out. It presents many features similar to the pyrrhotite ore body about to be described. The ore found here consists of pyrrhotite, magnetite, and subordinate chalcopyrite intergrown with brown-green augite. In places pyrrhotite predominates, in others magnetite predominates and locally they are commingled in equal proportions. This body of ore is bounded on one side by a thick zone of gouge, along which occurs iron-bearing jasperoid. These various iron deposits are unconnected with the body of sulphide ore described below.

THE PYRRHOTITE ORE BODY.[1]

A mass of sulphide ore known as the pyrrhotite ore body was encountered during the underground exploration of the mine 250 feet southwest of the magnetite deposits occurring at the contact. This body of sulphide is wholly enclosed in the granite and is therefore isolated from the other ore deposits. It is elliptical in plan; its dimensions being: length, 100 feet; maximum width, 18 feet; it has been stoped upward to a height of 10 or 12 feet. From it were extracted 2,000 tons of ore carrying four dollars in gold, 35 per cent. excess iron,[2] and 2 per cent. in copper.

The ore as seen in hand specimens consists of a mixture of pyrrhotite, chalcopyrite, and dark green to black pyroxene. The

[1] An abstract of this part of the paper has appeared in *Jour. Washington Acad. Sci.*, Vol. 2, 1912, p. 358.

[2] That is, iron in excess of silica; excess iron is the basis of the price paid by the smelter.

pyrrhotite was examined chemically by J. G. Fairchild in the laboratory of the U. S. Geological Survey and was found to contain no nickel. These three minerals are present in variable proportions; in sulphide-rich ore the pyrrhotite predominates strongly

FIG. 27. Pyrrhotite-augite ore, magnified 30 times; crossed nicols. Black areas represent pyrrhotite.

and with it is associated a subordinate quantity of chalcopyrite more or less evenly distributed in irregular particles. There are,

as a rule, however, numerous discrete particles of pyroxene, commonly anhedral, but occasionally partly idiomorphic, that are imbedded in the sulphides.

In order to determine the mineralogic features of the ore mass a number of thin sections were examined, material being taken in which the proportions of sulphides and pyroxene were approximately equal. Under the microscope the ore is found to be essentially an aggregate of monoclinic pyroxene, pyrrhotite, and minor

FIG. 28. Pyrrhotite-chalcopyrite-augite ore, crossed nicols. Dark stippled areas represent pyrrhotite, light stippled chalcopyrite. Drawn by H. F. Clark.

chalcopyrite. The pyroxene shows extinction angles up to 45°, and its refractive index β, as determined by the immersion method, is $1.71 \pm .01$. These properties indicate that the pyroxene is very probably augite. In places it is intergrown with a little pleochroic brown hornblende of the kind commonly found in deep-seated igneous rocks. Other silicate minerals that occur rarely are biotite, plagioclase, orthoclase, and quartz, but these constitute an insignificant proportion of the whole. The feld-

spars, quartz, and hornblende are in part present in the form of small blebs of granitic texture, not exceeding, so far as observed, an inch in size.

Texturally the augite constituting the gangue of the sulphides forms an allotriomorphic granular aggregate, as shown in Fig. 27. The pyrrhotite and chalcopyrite are closely associated (see Fig. 28), the chalcopyrite, as seen both with the unaided eye and with the metallographic microscope, forming small, separate and distinct, solid particles surrounded by pyrrhotite. Neither microscopic intergrowths, nor, on the other hand, veinlets of one sulphide traversing the other were seen. The available evidence appears to show that the two sulphides are essentially contemporaneous in origin. They occur either as interstitial masses between the augite grains, or as irregular intergrowths with them. It is noteworthy that the augite, although invariably anhedral where in contact with other grains of augite, shows a closer approximation to its idiomorphic outlines where it is adjoined or surrounded by sulphides. Characteristic quadratic cross-sections with truncated corners are occasionally found. The grains of augite, where enveloped by sulphides, are, as a rule, somewhat rounded and smoothed as if by corrosion, and are frequently penetrated by the sulphides in distinct embayments, which resemble those so common in the magmatically resorbed quartz phenocrysts of rhyolitic rocks. On account, however, of the general tendency of the sulphides and the augite to be intergrown in allotriomorphic fashion, exactly as are the feldspar and pyroxene in gabbroic rocks, and because of the erratic, inequigranular character of the aggregate, the textural evidence, considered alone, is perhaps not conclusive as to the primary igneous origin of the sulphides.

A zone of dark heavy rock of fresh appearance and even-grained granular texture surrounds and grades into the pyrrhotite-chalcopyrite ore body. As the wall-rock of a mass of sulphides its unaltered character immediately strikes the attention. This zone is well exposed by a tunnel crosscutting both sides of the ore lens. A specimen taken two feet from the edge of the ore lens, north

side, shows under the microscope an assemblage of plagioclase, augite, and pyrrhotite; quartz occurs rarely, and apatite and titanite are present as accessory minerals. The texture is hypidio-

FIG. 29. Pyrrhotite-augite diorite, magnified 30 times; crossed nicols. Pyrrhotite is shown by dark stippling. Drawn by H. F. Clark.

morphic granular, but is poorly developed and is in fact nearly allotriomorphic (see Fig. 29). At four feet from the periphery, the rock—a medium-grained granitoid of dark color—consists of

a hypidiomorphic granular aggregate of plagioclase ($Ab_{65}An_{35}$), augite, hornblende, in part poikilitically enclosing the other constituents, quartz which is as abundant as large anhedral grains, and minor orthoclase; and pyrrhotite, apatite, titanite, magnetite, and zircon as accessory minerals. At six feet from the periphery, the rock has changed to a medium-grained granitoid of gray color macroscopically showing lustrous hornblende and biotite associated with clear, vitreous or pearly feldspar. Microscopically it proves to consist of plagioclase ($Ab_{65}An_{35}$), orthoclase equalling or exceeding the plagioclase in amount, quartz, hornblende, and biotite, together with the accessory minerals titanite, magnetite, pyrite, apatite, and zircon. On the south side of the ore lens the same features are observable, but the transition zone is wider and the gradation outward is consequently less abrupt. At six feet from the periphery the enclosing rock is an equigranular, medium to fine-grained granitoid of dark color. It is composed of pyroxene and plagioclase in approximately equal amounts; in places it contains pyroxene-richer blotches carrying finely disseminated pyrrhotite. Under the microscope the rock is seen to be notably fresh and intact; it consists essentially of an aggregate of clear plagioclase ($Ab_{67}An_{33}$) and unaltered augite. The lack of idiomorphism of the augite occurring here is as pronounced as it is in the augite in the sulphide ore body. Hornblende, intimately intergrown with the augite in small quantity, biotite, orthoclase, and quartz are rare constituents, and apatite, titanite, titaniferous magnetite, and zircon occur as accessory minerals.

In short, it appears from the petrographic details of the preceding paragraph that the ore body is surrounded by a zone of augite-rich rock which may appropriately be termed a pyrrhotite-augite diorite.

The augite-rich rock grades laterally outward from the ore deposit, within a distance of six to twelve feet, to a quartz monzonite of normal composition and appearance. Such rock twelve feet from the south side of the ore lens consists of a hypidiomorphic granular assemblage of plagioclase ($Ab_{60}An_{40}$), orthoclase—the two feldspars occurring in approximately equal

amounts—quartz, biotite, and hornblende. A specimen taken fifty feet from the periphery of the ore lens shows essentially the same features, the only noticeable difference being that the plagioclase feldspar is slightly more calcic, having the composition corresponding to $Ab_{55}An_{45}$.

The general country rock north and west of the mine is a medium to coarse-grained quartz monzonite, apparently a phase somewhat richer in biotite and hornblende than the average rock of the batholith. It is cut by numerous small, irregularly-branching dikes of aplite, in places tourmaliniferous. The quartz monzonite of the batholith is a coarse-grained rock composed of labradorite, which is zonally banded, the large cores of the crystals measuring $Ab_{45}An_{55}$, orthoclase, hornblende, biotite and augite. The volumetric mineral composition as estimated under the microscope by Barrell is as follows:[1]

Labradorite, Ab_1An_1	34
Orthoclase with Na_2O	22
Quartz	25
Biotite	7
Hornblende	9
Augite	2
Magnetite	1
Apatite	.3
Titanite	.5
	100.8

A chemical analysis of this rock is available, the specimen being taken one mile from the contact with the sedimentary rocks at this locality;[2] it is typical of the general rock mass with which the ore body is associated.

ANALYSIS OF QUARTZ MONZONITE, ELKHORN.

H. N. Stokes, analyst.

SiO_2	64.31
Al_2O_3	15.44
Fe_2O_3	2.43
FeO	2.58
MgO	2.21

[1] *Op. cit.*, p. 538.
[2] *Op. cit.*, p. 536.

CaO	4.22
Na_2O	2.71
K_2O	4.09
H_2O at 110° C.	.19
H_2O above 110° C.	.79
TiO_2	.71
CO_2	None
P_2O_5	.22
S	Trace
Cr_2O_3	None
MnO	Trace
BaO	.07
SrO	Trace
Li_2O	Strong trace
Total	99.97

ORIGIN OF THE ORE BODY.

An explanation suggested immediately is that the ore body represents a mass of sulphides localized in an inclusion of limestone that either has been thoroughly altered by contact-metamorphism or has been dissolved by the magma. This explanation has at first glance much to commend it. The operation of general laws, such as are based on principles of wide application, is usually invoked to account for the segregation of magmatic ore bodies. Now, processes taking place in accordance with general laws should yield products or results of common occurrence; nevertheless, magmatic ore bodies are admittedly special and uncommon occurrences. The absorption of a mass of limestone by the magma, it might be argued, would bring about special conditions that would in some unknown way be favorable to the segregation of the sulphides during crystallization. There is, however, no observational evidence to support this hypothesis. In the vicinity of the ore body there are found inclusions of limestone—smaller in size than the ore body and therefore in all probability more susceptible to metamorphism—which have been intensely contact-metamorphosed, but they retain their sedimentary stratification and consist of an assemblage of silicates unlike those found in the pyrrhotite ore body.

As already shown, the texture of the sulphide ore, in so far as

it is of diagnostic value, is purely igneous, indicating, if the hypothesis suggested above be adopted, that the limestone had been completely dissolved by the magma. It would be expected, therefore, that the ore lens would show such minerals as are characteristic of the contamination of a magma by foreign inclusions, such as wollastonite, andalusite, and other silicates not commonly occurring in igneous rocks.[1] But no minerals of this kind are found.

Further, as not in harmony with this supposition is the fact that the feldspars actually become more calcic, that is, richer in lime, away from the ore lens, the range being from $Ab_{65}An_{35}$ to $An_{45}An_{55}$.

The hypothesis that the ore body represents an altered xenolith of limestone is therefore held to be untenable. The primary igneous origin of the sulphide ore body, on the other hand, is believed to be established by the following facts, stated summarily:

1. All the rocks, including that which composes the ore body and those which surround it, show an entire lack of pneumatolytic or hydrothermal alteration, such as the development of tourmaline, sericite, chlorite, carbonates, or other secondary minerals. They are fresh unaltered rocks in which the ferromagnesian minerals are notably lustrous and the feldspars clear and vitreous. Such minor alteration as was noted is plainly owing to slight post-mineral action.

2. There is a textural relation of the sulphides to the augite as shown by the tendency of the pyroxene to show idiomorphic boundaries against the sulphides. This is a feature not easily explainable other than by the hypothesis of an igneous origin.

3. The zonal arrangement of basic phases of the quartz monzonite around the ore body indicates that a marked differentiation has taken place in the magma concurrently with the segregation of the sulphides. This differentiation is expressed mineralogically by the decrease of plagioclase, orthoclase, and quartz, and the concurrent increase in ferromagnesian mineral as the

[1] Harker, Alfred, "The Natural History of Igneous Rocks," 1909, p. 338.

ore body is approached. The increase of ferromagnesian content, instead of appearing as hornblende or biotite, however, appears almost exclusively as augite in the ore body. It is noteworthy in this connection that if the differentiation took place through the agency of the mineralizers or the volatile fluxes of the magma, as believed by Michel-Levy, there is a conspicuous absence of fluorine-bearing and hydroxyl-bearing minerals in the final product. Contrary to what might be expected under this hypothesis, the minerals biotite and hornblende decrease in amount with increasing proximity to the ore body.

In conclusion, the notable features of this deposit as a member of the class of magmatic ore bodies are: (1) its segregation from a comparatively siliceous rock; other pyrrhotite-chalcopyrite bodies of this type have separated from magmas of gabbroic composition, (2) its relatively high gold content, which is unusual, as most ore bodies of magmatic origin are poor in gold.

LAND CLASSIFICATION: ITS BASIS AND METHODS.

W. B. HEROY.[1]

WATER RESOURCES.

The dominant factor in the development and use of the remaining public lands within the United States is water supply. The extension of agriculture and grazing, the development of mineral industries, transportation, and other varied activities, are directly dependent upon the quantity and quality of the underground and surface waters in what is, generally speaking, an arid region. To dispose of or to administer the remaining public lands without reference to their water supply is to ignore that natural resource which, more than any other, will affect their future utilization.

With a realization of this relationship between the public lands and their water supply the Geological Survey, almost from its inception, has been engaged in the work of securing definite information regarding the distribution and utilization of water to the end that the highest efficiency might be secured in its use, especially in those regions where the demand for water far exceeds the quantity available. When authorized, it has made classifications of the public lands with relation to their water supply. Under other conditions, where the laws have been inadequate to afford a basis for putting a proper classification into effect, it has, by a series of popular publications covering many years, sought to direct the attention of water users to the best methods of conserving and utilizing water. It is the purpose of this article to review briefly the progress made in this branch of land classification and to set forth the principles which guide its accomplishment at the present time.

The classification of lands with relation to water supply must be preceded by a knowledge of the water itself, its quantity, quality, and distribution. The fundamental facts thus obtained must

[1] Published by permission of the Director of the U. S. Geological Survey.

be studied from the standpoint of the probable uses to which the water will be put, taking into consideration distinctions between uses which leave the water substantially unimpaired in quality and undiminished in quantity, as water-power development; those which may impair its quality, as municipal use; and those which deplete its quantity, as irrigation. The forecasting of the probable future needs of a region and the consequent determination of the highest future use of its available water supply is a difficult problem and one where many factors now unknown or unappreciated may have important influences. Plans made for the future utilization of a water supply must involve as little sacrifice of present needs and growth as possible. Instances where there may be conflict between future development and present use must be carefully considered, harmonized where possible, and where conflict is unavoidable, preference given to the higher use. Typical examples of such conflict are seen in cases where it is sought to establish power plants in such locations that the subsequent use of the water for irrigation becomes impracticable and where agricultural and mineral claimants seek to acquire lands which are chiefly valuable in connection with water-power or irrigation development.

One of the greatest elements of uncertainty and confusion entering into the problem arises from the fact that the control of the utilization of water in the public lands states and territories is divided. While the public lands are subject to the control of Congress, appropriations of the water thereon have, in general, been left to the jurisdiction of the state. Thus, to divert the waters of a stream a settler must have the permission of the state; to construct across public land the ditch necessary to its use the permission of the general government is necessary. The general government in granting a right of way for a ditch has no assurance that the state will permit water to flow therein. On the other hand, the state, in authorizing an appropriation to divert water, has no assurance that the United States will permit its conduct across public land. This dual authority has resulted, on the one hand, in charges by state officials that state's rights

have been invaded in cases where federal officials have sought to control the use of water through the ownership of public land; and on the other hand, has given opportunity for the growth of serious abuses, in cases where neither state nor federal officials have exercised control of the situation, either because of supposed lack of authority or because of inefficient administration. This ever present problem can apparently be solved only when the proper state and national officials work in harmony to secure the highest good. Such achievement of this coöperation and such close definition of the spheres of federal and state authority that there shall be no broad zone within which both claim jurisdiction and neither exercises control are delicate tasks to which the next decade must be devoted.

The present status of land classification with relation to water supply can perhaps be best set forth by considering the important uses to which water is devoted in an arid region, proceeding from the primitive and elemental necessities to the complex and specialized uses resulting from modern conditions, indicating in each case the relation of the particular form of utilization to the disposition or administration of the public lands.

CLASSIFICATION AS REGARDS DOMESTIC USE.

The problem of domestic water supply in an arid region is closely associated with its agricultural development. In the broadest meaning of the term, the use of water for domestic purposes includes not only its use in the household, but by farm animals, by cattle on the range, and by the prospector in the desert wastes.

Permanent agricultural settlement depends upon the presence of a water supply suitable for household purposes and for farm use. Under homestead laws requiring as their fundamental conditions both residence and cultivation, the extension of settlement to new areas is possible only when the prospective homesteader finds water within a reasonable distance of his chosen location. Where water suitable for such use does not exist on the surface, the homesteader must resort to wells, and failing there, to haul-

ing water. The latter condition is one of hardship, for the labor, and therefore the expense, of securing the water by this method is great. Uncleanness and insanitation are almost enforced by the resulting economy of use. The conditions of water storage on the homestead do not usually tend to purity, and disease frequently follows. The possibility of securing a domestic water supply from wells in regions where surface waters are impure or altogether absent is thus a question of great importance.

In areas where the underground water resources are unexplored, geological investigation may determine the more favorable locations for putting down test wells, and in regions where the position of the water-plane is not known or is known but imperfectly the application of principles well known to the geologist may be of great assistance to the farmer and the well driller in forecasting the possibilities. To this end large areas in the arid region have been geologically investigated. The data relative to underground waters have been compiled and maps prepared, not only showing the position of the water-plane in proven areas, but indicating the probable location of the water-plane in adjacent unexplored areas. The data thus secured by the Geological Survey, often in coöperation with the states, are published and widely distributed as water supply and professional papers.

Depending upon the magnitude of the task, the securing of a water supply from underground sources may be a task for an individual settler, for a community, for a state, or for the nation. From the standpoint of the homesteader, the element of cost is an important one, and a limit is rapidly reached beyond which he neither has nor can secure funds for the drilling of a well. This limit varies somewhat with the value of the lands. Rich irrigable or "dry-farm" areas warrant greater expenditures for wells than less valuable lands where the arable area is small. In regions where the resources of a single homesteader have not been sufficient to meet the cost of dug wells, coöperative wells have been constructed. In other cases, enterprising men with capital have frequently traded upon their neighbors' necessities and secured large returns from the sale of water. In one instance a

well costing $1,300 was paid for in a little more than a year by an annual charge of $50 to $100 upon each of the neighboring families securing domestic water at the well. State aid has been extended in many cases, and legislation has been proposed in Congress making appropriations to improve the water supply of desert areas.

A modification of the homestead laws to relieve the entryman of the necessity of residence in cases where a domestic water supply is not available and can not be obtained, has been effected in two instances. In Section 6 of the act of February 19, 1909 (35 Stat., 639), applying to Utah, and Section 6 of the act of June 17, 1910, (36 Stat., 531), applying to Idaho, it was provided:

> That whenever the Secretary of the Interior shall find that any tracts of land . . . do not have upon them such a sufficient supply of water for domestic purposes as to make continuous residence upon the lands possible, he may, in his discretion, designate such tracts of land . . . and thereafter they shall be subject to entry under this act without the necessity of residence upon the lands entered.

This provision relating to domestic water supply has been construed by the Department of the Interior as referring not only to surface waters but to underground waters which could be reached by wells of reasonable depth.

In the determination of the existence of such a domestic water supply and in the recommendation of suitable lands for designation under the provisions of these acts, the Geological Survey, in regions where no potable surface waters exist, takes into consideration the depth below the surface and quality of the underground water, the amount of labor necessary to reach it by a well, and the cost of development compared with the agricultural value of the lands. The provisions of the law are considered particularly applicable in cases where substantial but fruitless efforts have been made to obtain such a water supply by digging wells.

Classification under these acts, while restricted by the water supply factor, also rests in part upon other provisions of each act which require that the land must be susceptible of a certain amount of cultivation. The Department of the Interior also

holds that the lands must have sufficient rainfall to mature crops by "dry-farming" methods. In securing data for classification of lands of this class the Geologic Survey has been assisted by special agents of the General Land Office. To January 1, 1913, 1,199,638 acres had been designated in Utah, and 7,801 acres in Idaho as not having a suitable domestic water supply.

The problem of the disposition of grazing lands is still largely unsettled. By the creation of national forests a large part of the summer range has come under the general scheme of forest administration, and is leased by the Forest Service on a per capita basis, but the unreserved public lands still include considerable areas of summer range, much of the fall and spring range, and a large proportion of the winter range. The control of the spring, summer, and fall range is rapidly passing into the hands of individuals and live stock associations, not in general by securing title to the public lands as a whole, but by the simple expedient of acquiring title to the water holes. The owner of the springs and streams located on an otherwise waterless range has secured tenure to the grazing land on far more favorable terms than if he had acquired absolute ownership. He is free from state land tax, he pays no rent to the government, and no rival sheep or cattle man may water at his wells. Except for the period when snow, by providing water, may make invasions by rival stockmen possible, he is secure in his possession.

As a remedy for this situation, disposition of the grazing lands by sale and by lease has been advocated and several bills dealing with the situation have been introduced in Congress. If, as is advocated by the Interior Department, a leasing system is adopted, it is apparent that the government would be at a serious disadvantage in proper administration unless watering places were also available for lease. As a step in the working out of a definite policy for the administration of public grazing lands outside of national forests the withdrawal of public watering places under the authority conferred by the act of June 25, 1910 (36 Stat., 847), has been sanctioned by the President. The first withdrawal for this purpose was approved by him on March 29, 1912.

These withdrawals are based upon field investigation by members of the Geological Survey and in some cases upon reports of General Land Office inspectors. Careful consideration is given in each instance to the relation of the watering place to the surrounding range and its value in connection with grazing on the public lands. Agricultural lands susceptible of successful cultivation have been excluded from withdrawal except in cases where the watering places in a region have largely passed into private ownership and it becomes imperative to reserve some water for stock purposes, even at the expense of settlement.

CLASSIFICATION AS REGARDS IRRIGABILITY.

The first orderly and scientific classification of the public lands which was specifically authorized by Congress was for the purpose of fostering irrigation. The duty of making this classification was placed upon the Director of the Geological Survey by the act of October 2, 1888 (25 Stat., 505, 527), in which an appropriation was made

"for the purpose of investigating the extent to which the arid region of the United States can be redeemed by irrigation, and the segregation of the irrigable lands in such arid region, and for the selection of sites for reservoirs and other hydraulic works necessary for the storage and utilization of water for irrigation and the prevention of floods and overflows, ..."

The areas necessary for such irrigation works and all the lands made susceptible of irrigation thereunder were to be reserved from sale as the property of the United States, subject to their restoration to entry under the homestead laws by the President.

Thus was laid the foundation for a comprehensive study of the water resources of the arid West. But, as Major Powell said in the first annual report[1] of the Irrigation Survey, which was thus initiated,

"the problem of the best disposition of the arid lands remains. It is a problem of profound importance and it presses for solution. Many thousands of persons are already in that country and eagerly desirous

[1] Tenth Annual Report of the Director of the U. S. Geological Survey, Part II., "Irrigation," p. 28.

of establishing homes for themselves, and they are debarred therefrom because the land system which now exists, a system which was the growth of time, and to which the highest statesmanship had been devoted for a long term of years, was adapted to the physical conditions which prevail in humid lands, and is not adapted to the conditions which prevail in arid lands. The march of settlement in its progress westward has reached a region of country where the physical conditions and limitations of agriculture differ altogether from those prevailing in the regions first settled, and problems are presented new to us and unknown to our ancestors, who came from northern Europe, but very old to the people of southern Europe and of other regions of the earth. In fact, the earliest agriculture known to the world was that which was carried on by means of irrigation."

The work thus auspiciously begun was in most respects short-lived. By the act of August 30, 1890 (26 Stat., 391), the appropriations for the irrigation survey were discontinued, and certain of its powers, including that of the "segregation of the irrigable lands," were rescinded. The provision for the survey and selection of reservoir sites was, however, continued, and the important work of stream measurement was left unimpaired in principle, although the amounts of money which could be allotted for the work were, from 1890 to 1894, barely sufficient to maintain some of the most important stations and preserve from loss valuable data already secured.

The technical studies of stream flow and the distribution of water, which had been initiated in connection with the work of the irrigation survey, were found equally useful in the development of the more humid portions of the United States. As a successor to the irrigation survey there thus came into existence the Division of Hydrography of the Geological Survey, which continued the technical investigations, but the work of land classification as a part of the system for the administration of the public lands practically ceased.

The Reclamation Act of June 17, 1902 (32 Stat.; 388), was, however, a direct outgrowth of the hydrographic work of the Geological Survey, and the Chief of the Division of Hydrography became first the chief engineer and later the director of the Reclamation Service. But this organization, created primarily to con-

struct irrigation works under national auspices, neither took over nor was given any general functions relative to the classification of the public lands. The exploratory work of the irrigation survey now bore its first fruit, for many of the irrigation projects and reservoir sites which had been surveyed in earlier days were developed by the new organization. The measurement of streams and other types of hydrographic work were continued by the Geological Survey and are now functions of its Water Resources Branch.

The movement for the disposition of the public domain in accordance with its highest use, a logical development of the conservation idea, has led to the application of the information thus gathered regarding the water supply to the solution of many problems related to irrigation. The connection of the Geological Survey with this movement is in part advisory and in part administrative. Peculiarly enough, the first demand made upon the Survey for the classification of public lands with relation to their water resources was for the designation of non-irrigable lands, the reverse of the problem which confronted the old irrigation survey.

The development of scientific dry-farming and its extension to wide areas of semi-arid lands as a result of special methods of tillage and of the success achieved in several years of more than average precipitation caused wide areas to be entered under the homestead laws. The most approved systems of dry-farming, however, require summer fallowing, each piece of ground being cropped in alternate years. The net result of following this method is to reduce the annual productive acreage one half. The area which it was possible to enter under the homestead law thus appeared to be too small to support a family and in response to the demand for relief which followed, the 320-acre homestead acts were passed. The acts of February 19, 1909, and June 17, 1910, previously referred to, and the act of June 13, 1912 (Public No. 191), place upon the Secretary of the Interior the duty of determining what lands are enterable thereunder by a proviso:

"that no lands shall be subject to entry under the provisions of this act until the lands shall have been designated by the Secretary of the

Interior as not being in his opinion susceptible of successful irrigation, at a reasonable cost, from any known source of water supply."

The Director of the Geological Survey was instructed by the Secretary to make recommendations of lands suitable for designation thereunder, and in pursuance thereof nearly 193,000,000 acres have been designated in the ten states and territories to which the provisions of these acts apply. Of this area, approximately 157,000,000 acres were designated en bloc within three months after the passage of the earlier acts. This result was achieved in part by the use of the topographic maps, the accumulation of thirty-five years of work, in connection with a large number of which unpublished land classification sheets were on file, in part by the application of rainfall, run-off, and stream measurement data, in part by consultation with the Reclamation Service, and in part by the coöperation of several state engineers. Needless to say, this work was at times in error, as a result of the rapidity which was required in its execution, but the fact that cancellations of erroneous designations affect, in the aggregate, only 615,492 acres testifies to the high degree of accuracy reached.

Since the first general designations above referred to were made, numerous requests have been received for the designation of additional areas. Such requests, referred to as enlarged homestead petitions, often require special field examinations in order to determine the character of the lands. In cases where the lands petitioned for adjoin present or proposed irrigation developments, the determination of their irrigability has not always been obvious. While the possibilities of irrigation by gravity methods have, for large areas of the public domain, been quite satisfactorily determined, the field opened by the application of irrigation by pumping is as yet much less well known. Hence in many of the closed valleys of the great basin region the Survey has refused to recommend the designation of areas where the underground waterflow lies within 50 feet of the surface, in the belief that efficient and economical pumping equipment and cheap power will afford a means by which such lands can be successfully irrigated. All known artesian areas have been carefully excluded

from designation under the enlarged homestead acts, except where the flows are known to be insufficient for irrigation purposes.

The act approved August 18, 1894 (28 Stat., 372, 422), known as the Carey act, was the first to provide for the reclamation of public lands on a large scale. The older desert land act was entirely inadequate as a foundation for large irrigation enterprises, requiring as they do that adequate security shall be furnished during the construction period for the considerable financial investments necessary for such development. The original Carey act and the acts since passed in amendment of it, provide for reclamation through the agency of the respective states, and the provisions of these statutes have now been accepted by nine states. The plan is, in brief, that the state shall show an adequate source of water supply and present a feasible plan of reclamation for the public lands proposed to be irrigated under the particular project, and, if these features meet with the approval of the Secretary of the Interior, a contract is executed with the state for the reclamation of such lands. The state in turn generally contracts with a private company to do the actual work of construction. Under the terms of the act the state is given ten years to complete the work. If at any time before the termination of this period the state shall have reclaimed any of the lands segregated, it may apply for patent, and if it then appears to the Secretary that the state has fulfilled its contract by the construction of the irrigation works proposed in the original plan of reclamation and by the attachment to the lands reclaimed of a valid perpetual water right, patent will issue.

In the earlier years of the operation of the act, the adequacy of the plan of irrigation submitted by the state and the sufficiency of the water supply for the complete reclamation of the lands were not closely scrutinized by the Department of the Interior. The scheme was frequently indefinite even in essential features, and the segregations authorized by the act were made with the idea of giving the state the fullest opportunity to work out a project, the reports and estimates of state officials and of repre-

sentatives of proposing companies being freely accepted at face value. As a result areas were segregated in excess of the limits of practicable irrigation from the available water supply, and public lands were thus unnecessarily withdrawn from other use for a period of ten years. As the states, as well as the general government, were lacking in experience, contracts with the proposing companies were often loosely drawn and failures resulted, the brunt of the loss falling upon the settler. Even in the case of well-constructed projects there were instances where water rights were sold greatly in excess of the amount warranted by the water supply.

The publicity given to the failure of several enterprises of this character, resulting as they did in severe loss to settlers who had located and made improvements on the lands in advance of actual reclamation, showed clearly the need of much more careful inquiry into proposed Carey act developments, and radical changes in administration were inaugurated. Under the present practice, therefore, the project is looked over on the ground by an inspector of the General Land Office, who secures such information as is available regarding the details of the project. Upon receipt of his report the application is referred to the Geological Survey and a careful analysis is made of the water supply for the project, and sufficient estimates of cost and returns made to show that the construction can probably be accomplished at a figure warranted by the value of the lands when reclaimed. In cases where the data relative to the amount of water available for the project are insufficient for the determination of the acreage which can properly be supplied with water, a hydraulic engineer of the Geological Survey may be instructed to supplement the available information concerning the water supply by stream gagings and such other data as can be obtained by a field investigation. When all the facts at command are analyzed, a satisfactory estimate of the allowable acreage can usually be made. Since in many instances the area applied for by the state is in excess of that which can be reclaimed with the available unappropriated water, a usual adjustment is by the reduction of the area. In a few instances

the status of prior water rights has been so chaotic that the Geological Survey has been unable to recommend the segregation of any lands whatever. In other cases a year's stream gagings or an adjudication of the prior rights are required as prerequisite to action upon the application. The aim of the work as now conducted is to make the approval of a segregation list something more than a mere formal action, and every precaution is taken to safeguard the welfare of the prospective settlers as well as the necessary investment of capital and the interest of the government.

The act of March 15, 1910 (36 Stat., 237), has facilitated the development of Carey act enterprises in that it permits the Secretary to withdraw from entry for one year the lands which will presumably be included in a project, in order that a satisfactory plan of reclamation may be worked out and formal application for segregation made. By thus preventing intervening entries, time is given for a much more careful presentation of the project than was possible under the previous conditions.

Much closer attention is paid also to projects in the course of construction and settlement than heretofore. Where data, secured after the segregation is made, indicate that projects exceed a conservative acreage, or when information is received that constructing companies are attempting to increase the irrigated area by selling water rights to private lands and thus deprive segregated lands of a portion of the water supply necessary to their complete reclamation, conferences are held with state authorities and prompt measures taken to insure the protection of settlers. It is hoped by these means to place future development under the Carey act on a conservative basis, eliminate, so far as possible, speculation, and, in so far as the general government has the power, insure to the settler who seeks a home on segregated lands, that he will get what he pays for. This use of the water supply data available in the Geological Survey, while not involving direct classification of lands, is closely related to, and administered in harmony with, its land classification work.

Withdrawals of sites for irrigation reservoirs are made when-

ever the investigations of the Geological Survey indicate that feasible locations exist. The withdrawal power has also been used to withhold from adverse possession reservoirs required in connection with large irrigation projects, both public and private, pending precise surveys and the granting of appropriate rights of way.

CLASSIFICATION WITH RELATION TO WATER POWER VALUE.

The influence which the United States may exercise over water power development rests upon its constitutional authority to control navigation, and upon its ownership of public lands. Whereas the supervision of water power development of navigable streams is usually recognized as being merely incidental to the improvement of navigation, the authority which may be exercised over the public lands is absolute, and the power of regulating water-power development where public lands are affected is correspondingly great.

That particular tracts of public lands might have value for water power has long been recognized, for the early surveyors of the public lands were required to report all "mill seats" observed. The recognition of the fact that lands valuable for power purposes should be removed from the ordinary course of disposition and specially administered, came, however, only after the realization of the enormous values which such lands might hold in consequence of the application of electricity as a means of power transmission. The first segregations within the public domain of lands valuable for power were made under Secretary Garfield. Under his direction the Reclamation Service selected certain power streams and recommended the withdrawal from disposition of bordering lands. Shortly after the beginning of the administration of Secretary Ballinger the Geological Survey was instructed by him to "make an investigation of water-power sites on the public domain, outside of national forests, which are not included in withdrawals for reclamation purposes, with the view to securing at the next session of Congress legislation to control and regulate their disposition" and recommend the necessary reservations.

Under these instructions the work of withdrawing lands valuable for power purposes has continued, subject, however, to the provisions of the act of June 25, 1910 (36 Stat., 847); Secs. 13 and 14 of the act of June 25, 1910 (36 Stat., 855); and the act of August 24, 1912 (Public—No. 316), which give specific authority for withdrawals previously made under the general powers of supervision over the public lands vested in the Secretary of the Interior.

In carrying out these instructions, the Geological Survey has defined the term "water-power site" as including any lands valuable in connection with power development. So rapidly has hydraulic engineering advanced that a diminishing proportion of the great hydro-electric developments of the United States are located at points where nature has given unusual opportunities for power development by great concentration of the fall of streams. Natural water powers, water-falls and rapids, are generally the first to be developed because the cost of construction is usually less per unit of power developed. After the water-falls in a region are harnessed, the demand for power makes profitable the development of less favored sites. Then, as a last step, comes the creation of power sites on streams where through evenness of slope no marked opportunities for the development of power exist. Lands adjacent to such natural power sites as those at Snoqualmie Falls and at the Great Falls of the Missouri are thus of great value for power purposes, but it is no less true that lands along the Connecticut, the Tennessee, or the Colorado may have power value even though there may be no such marked concentration of fall. The term "power site" is thus used in a broad rather than a restricted sense.

What constitutes a water-power site, or opportunity for present or future power development depends upon the physical characteristics of the stream, and its relation to adjacent water power and markets. A power stream is one which by reason of volume of water, regimen, slope, and character of valley affords opportunity for feasible power development. Where the gradient is steep, development may be of the high-head type, securing con-

centration of fall by diversion of water in a conduit. Where the gradient is gentle, dams are constructed to secure the necessary head, the power house being placed at or near the dam, thus forming a low-head development. No clear line of demarcation can be drawn between these types, and intermediate forms of development in great variety exist.

The problem of determining what public lands have water-power value where the stream is suited to low-head developments is relatively simple. The complete development of the power possibilities in such cases will depend primarily on the occurrence of suitable sites for the construction of dams of such height as to divide the stream into a succession of pools. A careful topographic survey of the stream is first made by skilled topographers. The hydraulic engineer, using the resulting topographic map as a basis, studies the possible dam and power-house sites, the available data relative to the discharge and fluctuations of the stream, and the possibility of its improvement by storage reservoirs. A single scheme or alternative schemes of development are then worked out, providing for the greatest practicable ultimate utilization of the river, and the legal subdivisions which include areas necessary for flowage and power development works are withdrawn from disposition. Existing developments are taken into consideration in the formulation of such a comprehensive plan, and additional data are frequently secured from surveys or water filings made by power companies which own or control flowage rights.

In the case of high-head developments, the problem increases in complexity because of the number of alternative developments which become possible. Such a project will in general include a diversion dam, usually forming a small reservoir, a conduit conveying the water to a forebay reservoir, and pressure pipes conducting the water from the forebay to the power house. It is obvious that the location of structures of this character affords opportunity for wide variation, depending largely upon the ideas of the designing engineer. It is occasionally even difficult to determine which side of a river affords the more economical con-

duit location, for frequently the shortest line is more than offset by difficulty of construction. There are, however, certain features which can be determined which in many cases serve to fix the limits of the portion of a river to be included in one development. Thus the intake may be placed just below the mouth of an important tributary, not only to secure the additional water which it contributes but because a diversion at a higher point might necessitate carrying the water by flume or siphon across the tributary valley. Such a junction is also frequently the best site for a diversion dam, since flowage, and hence storage capacity, is secured both on the main stream and the tributary. The length of the conduit and the portion of the stream to be included in one unit depend largely on the slope. The location of the power house is governed by such factors as the location of the intake of the next development downstream, by the length of pressure pipe required, and by the topography of the site itself.

Until, therefore, actual construction is completed and the power possibilities of a stream are harnessed it is seldom possible to state absolutely that certain tracts of land and those only will be utilized for power development. The only alternative is to include in power withdrawals such lands as would be required for the location of structures under such alternative development schemes as may appear feasible. Withdrawals of this type can scarcely be considered classifications in the sense in which the term is used with relation to agricultural and mineral character, and in most cases no strict classification is possible. Under existing legislation, however, no other alternative method is available of retaining water-power sites in public ownership.

The withdrawals thus doubtless include lands which will never be actually utilized for power development. If, however, the withdrawals were made to include only one possible development and the lands necessary to other possible developments were allowed to pass into private ownership, the power site would have passed from public control just as effectually as though all the lands had been restored.

This withdrawal of public lands as a safeguard against the

alienation of the water power necessarily withholds the land from other forms of development. It is patent that a large portion of a forty-acre legal subdivision might be utilized for agriculture or mining without interference with a water-power conduit on the same tract. In other words, two uses of the same tract of land at the same time are possible. A parallel case arises where coal is mined from under land at the same time that crops are raised on its surface. Such diversified use of the lands is to be encouraged as promoting the fullest possible development of our natural resources. In the situation which has arisen because of water-power withdrawals, it has been suggested that provision be made by act of Congress by which lands determined to have such possible power value may be patented with the reservation to the United States or its assigns of the exclusive right to use the land for power development, with payment to the owner of actual damages incurred from such use. Such a reservation of water-power rights would be similar to the reservation of the coal provided for in the act of June 22, 1910 (36 Stat., 583). A bill (S. 7362) has been introduced making such provision with relation to Indian lands valuable for power purposes, and the extension of the principle to all public lands withdrawn for power purposes appears desirable.

In accordance with the general principles above outlined, about 1,800,000 acres have been withdrawn from the public domain because of water-power value. The activities of the Survey have, however, not been confined to making withdrawals of lands valuable for power, but, under the Secretary's instructions, the Geological Survey has classified large areas as being without power value. Careful regional studies of the public-land states have been made and office maps have been prepared, or are in preparation, indicating areas within which no important power possibilities are known to exist. By the use of these maps the Geological Survey has reported to the General Land Office as being without power value, areas many times larger than the total area of lands withdrawn for this purpose. The elimination of the lands without power value and the retention of the lands

which have power value thus becomes in effect a classification of the public domain from a water-power standpoint.

THE ADMINISTRATION OF THE RIGHT OF WAY ACTS.

A form of appropriation of public lands which is entirely unrelated to the ordinary disposition by legal subdivisions and by which most important privileges are conferred is designated under the general term "right of way." A right of way is in its fundamental meaning merely a right of passage across another's property, and the term in itself conveys no idea as to the extent or duration of the right. Thus it may amount to a mere permit or may be a license, a lease, an easement, or a qualified fee.

Congress in its desire to promote the fullest possible development of the public lands has by various acts granted numerous rights of way, both to specific beneficiaries and by general acts to all properly qualified applicants. The estate granted by Congress has varied greatly and the term "right of way" as used in the statutes and as interpreted by the courts has been given many shades of meaning, the rights acquired being sometimes specifically defined, again only determined after the most careful scrutiny by the highest courts of the land.

The range of purposes for which such rights have been granted is great. Practically all of them, however, fall into three main groups,—transportation, communication, and water utilization. Rights of way for transportation purposes, beginning with wagon roads, now include railroads, tramways, and oil pipe lines. The post road has now been supplemented by the telegraph and the telephone. Great as has been specialization in methods of transportation and communication, the development of methods of water utilization and attendant hydro-electric power transmission has been even more rapid and the various acts authorizing rights of way for the use of water now authorize the granting of a wider range of privileges than the acts relating to the other classes. An unfortunate feature of the statutes relating to rights of way for water utilization is that taken as a whole they present no well-ordered scheme for the development of the water re-

sources of the public domain. Obscured by ambiguities of wording, overlapping in scope, and often indefinite as to the estate contemplated, they are a source of constant uncertainty to the applicant and a vexation of spirit to the conscientious administrative officer attempting to work out an orderly administrative policy.

It is scarcely within the scope of this article to attempt an exposition of the various right of way acts relating to the conduct of water over public lands. Volumes of briefs on the subject have been written and at the present time many questions of fundamental importance have not been decided by the department, much less by the courts. It is desired, however, to make brief reference to the more important right of way acts and review a few of the problems which arise when the proposed rights of way are considered in relation to their effect upon the proper development and use of natural resources.

The general railroad acts of March 3, 1875 (18 Stat., 482), and March 3, 1899 (30 Stat., 1233), grant rights of way for various uses connected with railway operation, the title acquired having been decided by the Supreme Court to be a qualified fee. Rights of way under these acts may be acquired either by prescription as a result of the actual construction of a railroad line, or in advance of construction by the approval of the Secretary of the Interior. Since stream valleys, because of the low gradients afforded, frequently present favorable routes for railroad construction, many railroad rights of way which closely parallel water courses are presented for approval. The locating engineer, naturally desirous of securing the location which appears most favorable when cost of construction and ease of operation are considered, may disregard entirely the other uses which the stream valley may have. Thus storage reservoir sites and water power sites may be virtually destroyed or their development saddled with the cost of removing the railroad to a new location. While the construction of the railroad on a location which does not interfere with power and reservoir sites can sometimes be effected only at an increased construction cost and at a sacrifice

of alignment and gradient advantages, careful study frequently shows that equally favorable routes which do not so interfere may be selected. In other cases, some sacrifice upon the part of the transportation interests becomes necessary to preserve the practical possibility of power and reservoir development. It must be recognized, however, that a stream valley may have great value as a transportation route as well as for power purposes, that frequently the construction of the railroads and the development of markets for the adjacent region must precede any market for the power or use for the reservoir, and that the presence of the railroad may so reduce the cost of developing the power as to be a decided asset. Hence it can scarcely be considered equitable to tax present transportation development with the great expense which would sometimes be necessary to eliminate all interference with future power development. Such a distribution of the burden should be effected that both types of development can be made and the increased cost be equitably adjusted. The Geological Survey has for several years acted as an adviser of the Secretary in these matters, basing its recommendation in exhaustive field and office studies of the technical features of the railroad application, combined with the preparation of comprehensive plans for stream improvement and use.

Rights of way for irrigation works may be acquired either under Secs. 18 to 21 of the act of March 3, 1891 (26 Stat., 1095), or under the act of February 15, 1901 (31 Stat., 790), but since the former grants a qualified fee and the latter a revocable license, practically all irrigation applications are filed under the earlier act. In connection with these applications the Geological Survey is required to report upon the feasibility of the proposed scheme, upon its relation to proper irrigation development in the locality, upon possible interference with water-power development, upon the relative value of the right of way for power and for irrigation use, upon the methods by which the applicant proposes to control the lands to be irrigated, and in important cases, upon the financial ability and bona fides of the applicant.

Four general acts now in force provide for the use of rights of way for power development and transmission. They are the

act of May 11, 1898 (30 Stat., 404), amending the act of March 3, 1891 (26 Stat., 1095), the act of February 15, 1901 (31 Stat., 790), the act of February 1, 1905 (33 Stat., 628), and the act of March 4, 1911 (36 Stat., 1235, 1253).

The first of these provides that approved irrigation rights of way may be used "for the development of power, as subsidiary to the main purpose of irrigation." It is apparent that all forms of power development are not permissible under this act but just what types of development and uses of power are "subsidiary" has not been closely defined. The act of 1891 gives a permanency of estate which is highly attractive to developing companies and in consequence many applications have been presented which in the guise of irrigation development involve large commercial power values. The true purpose of the applicant can sometimes be inferred from water filings made under state laws and other similar records, but the disposition of such applications must generally rest upon a careful comparison of the value of the rights of way for power and for irrigation, the application being denied when the power value so far exceeds the irrigation value as to make the irrigation factor appear of minor importance.[1]

The act of February 15, 1901 (31 Stat., 790), the general water-power act, authorizes the issuance of permits which confer no rights in the lands crossed and which are revocable in the discretion of the Secretary of the Interior. While the tenure thus given is so insecure as to make the financing of hydro-electric propositions based thereon difficult, the fact remains that this is the only act under which rights of way for ordinary commercial power development may be acquired. Congress has been repeatedly urged to strengthen this act by authorizing the issuance of long-term leases. Regulations approved August 24, 1912, under this act place upon the Director of the Geological Survey the responsibility for the compliance of the applicants with conservation principles and for the working out of technical details. The act of 1905 grants rights of way "for mining or municipal pur-

[1] Decisions of the Department of the Interior in cases relating to the Public Lands, Vol. 40, p. 380, ex parte California-Nevada Canal, Water and Power Co.

poses and for the purposes of the milling and reduction of ores," within national forests only. General commercial use of the power so generated is apparently not contemplated by the act.

The act of 1911 authorizes the granting of an easement for rights of way for transmission lines for periods of not more than fifty years and except in the fixity of tenure prescribed is similar to the act of 1901.

These acts providing for water-power development and transmission are based on a consideration of the *purpose* of the development rather than its *character,* upon the intent which the applicant expresses rather than what he actually does after the grant is made. However this method of legislation may tend to foster certain industries, such as irrigation or mining, it becomes apparent that from an administrative standpoint it presents grave difficulties. While an applicant might be quite sincere in desiring to use power in connection with the development of a mining property, the lapse of time might see the mine closed and the power devoted to commercial uses. A corporation which now proposes to use power in pumping water for irrigation might in time find the commercial power market more attractive and abandon the original irrigation uses, although the water-power development itself might undergo little or no modification with this change of purpose. Under these conditions the determination of whether or not an application comes within the purview of the particular act or acts which are invoked is frequently a task of much difficulty, since the consideration rests not upon questions of fact alone, but questions of intent.

In concluding the discussion of this phase of land classification it must be emphasized that any classification of the public lands, no matter how painstaking, loses its chief value if the laws providing for disposition are not in harmony with the classifications made, but at this point the responsibility of the administrative officer and his technical and scientific assistants ends. The responsibility and the remedy must be left in the hands of an overburdened legislative branch of the government, hitherto unable or unwilling to devote the time necessary to reach a proper solution of the problem.

A REMARKABLE CARBONACEOUS DEPOSIT NEAR PUTNAM, NEW MEXICO.

WILLIAM FOSTER.

INTRODUCTION.

Several years ago the attention of D. M. Barringer, of Philadelphia, was called to a remarkable black, carmel-like deposit, which occurs in large quantity near Putnam, New Mexico. Samples of the material were sent by Mr. Barringer to a number of well-known chemists, geologists and mineralogists in various parts of the country for the purpose of investigation.

On receipt of their reports, some of which were preliminary, it was seen that they were not in agreement. One chemist of high standing reported as follows:

"The black material is certainly a curious substance. . . . It seems to belong to the ill determined and imperfectly studied class of humoid or caramel-like derivatives of the carbohydrates."

In another report the following statement is found:

"I may say to you frankly I do not know what the stuff is nor what it can be used for."

Another said:

"It contains a small amount of combustible matter which reminds me of lampblack. . . . It seems to contain nothing bituminous."

A firm of analytical chemists stated that they could not bring themselves to believe that the material was an altogether natural product, but rather a solution of the inorganic salts in a sugar syrup, by the aid of the fruit acids which they failed to segregate! The same chemists also said:

"The organic matter present we find to be, chiefly, caramel. . . . The original was soluble in water."

Still another chemist of a well-known firm reported:

"I find that the solution in water will reduce Fehling's solution to an extent that corresponds to 8.86% glucose, but this amount would hardly be of value even if washed out of the whole valley."

In another letter the following statement is found:

"Throw this [the material] into cold water and you will notice how wonderfully soluble it is. This is what first attracted my attention. I had supposed the material to belong to the series of asphalt minerals, . . . but as soon as I noticed this peculiarity, of course I knew I was on the wrong track, and I have not the faintest idea what the stuff is. It seems to exist in such enormous quantities that it is a little odd that we can find no reference to anything similar to it in any of the mineralogies."

Now, on account of the conflicting opinions expressed by various scientists of high standing, it appeared that the deposit was a rather remarkable one, and that it was well worth while to have a more thorough investigation made with a view to the publication of the results. Accordingly, at the suggestion of Mr. Barringer and my colleague Dean W. F. Magie, who very kindly furnished me with samples of the deposit, the investigation of the problem was undertaken by the writer, who arrived at the conclusion that the material is a *peaty formation* mixed with a large quantity of mineral matter, principally silicate of aluminium and sodium. On account of the very finely divided condition of the organic part of the deposit, it forms, with water, a *colloidal solution* rather than a true solution. Failure to observe this fact, was, in the opinion of the writer, one of the chief causes which led to the conflicting opinions as pointed out above.

OCCURRENCE.[1]

The deposit is located in the northwestern part of New Mexico, about fifteen miles northwest of Putnam, and marked on the old maps Pueblo Bonita. It is on a high plateau—4,000 to 5,000 feet—adjacent to the Navajo Indian Reservation. Holsinger visited the locality and examined the deposit at two places, each distant from the other about four miles. Here the country is undulating, but over larger areas almost level. The deposits were pointed out by

[1] Private communication from S. J. Holsinger, Meteor P. O., Coconino Co., Arizona.

Indians, but at that time there were no surface indications of the presence of the black material—not even discoloration of the sand which everywhere covered the ground. These locations were on a broad, flat wash having a drainage towards the northwest and into Chaco Canyon. This was between Coal Creek and Chaco Canyon. The first pit encountered the deposit in a liquid state about three feet below the surface. A hole was sunk to a depth of four feet, and as fast as the material was baled out it filled to a depth of one foot. The second pit was dug about four miles south on the same broad wash. At three feet a stratum of white clay was encountered in which there was a black band seam of the deposit. This clay was about a foot thick. After passing the clay the deposit was encountered, which was of the consistency of hard gelatin. It was dug into to a depth of ten to twelve feet without passing through it. Eight or ten miles north of the deposit are what are known as the Bad Land shale beds in which are vast numbers of fossils, including the prehistoric horse and large mammals. Holsinger saw several very large tusks and two very large skulls. In the near vicinity of the deposit the rocks are sandstone of very peculiar form; it has the appearance of having been burned. Pieces of it would ring like metal when struck with a hammer. The rock was weathered so as to have butts full of seams and pits and shaly remnants. Coal beds are known to exist north and south of these deposits.

The following supplementary information was obtained from Mr. Barringer, who interviewed a Mr. McCullough, who made the expedition to secure the samples: Indians living in the locality say the deposit is ten miles long and several wide. The deposit is of unknown thickness, but has been met with up and down this branch of the Chaco Canyon wherever the Indians have tried to sink wells for water. There is no indication whatever on the surface. In places it is under a stiff white clay which covers a wide flat valley. Above this there are sand and soil, and there are many petrified trunks of trees lying on the surface, an indication possibly of hot alkaline water action. At other places it is found beneath the superficial sand and soil without the covering

of white clay. It is a great coal country and coal crops out in all the neighboring canyons. The rocks are principally sandstone, shales, and some thin strata of limestone. Fossil remains (heavy bones, etc.) are abundant in the near neighborhood in the shales. The deposit was about four feet below the surface and it seemed to be more dense the deeper it was dug into. The material is black when dug, and it appeared to lie above all coal beds observed, but doubtless some of these have been eroded off. According to McCullough, the strata in the locality are perfectly horizontal. On consulting "A Reconnaissance Survey of the Western Part of the Durango-Gallup Coal Fields of New Mexico and California," published by the U. S. Geological Survey, I find that the region between Coal Creek and Chaco Canyon is described on the map as follows:

1. On the north—Laramie Formation (coal bearing).
2. On the south—Mesaverde Formation (coal bearing).
3. In the middle—Lewis Shale (not coal bearing).

These formations belong to the *Upper Cretaceous*.

ANALYSIS.

The sample analyzed was obtained by McCullough. It was of the consistency of stiff gelatin.

WATER.

1. A sample was dried in an air bath at 100° to constant weight. Per cent. of water, 53.69.

2. A second sample was dried over sulphuric acid at a low pressure. Per cent. of water, 53.74. There was no apparent decomposition in either case, and the results are in close agreement. The dried material is black, hard and brittle, and when ground up finely it resembles coal dust.

ANALYSIS OF THE DRY MATERIAL.

A sample of the material was burned at as low a temperature as possible in a flat-bottomed platinum dish, and the ash was treated with hydrochloric acid. No carbon dioxide was evolved,

thus showing that the ash did not contain carbonates. When the dry substance is heated below redness, it gives off vapor having rather an unpleasant odor, and at a higher temperature it burns, leaving a brownish ash. When heated with a blast lamp to constant weight, it takes on a reddish color.

The analysis of the dry material is as follows:

	Per Cent.	Excluding Mineral Matter, Per Cent.
Ash	53.53	
Carbon	26.04	56.04
Hydrogen	3.14	6.76
Nitrogen	0.95	2.04
Oxygen	16.34	35.16
	100.00	100.00

The composition of this material, excluding the mineral matter, corresponds very closely to that of peat, which falls in between wood and lignite. The following is the average composition of these fuels, *free of water and ash*:[1]

	C, Per Cent.	H_2, Per Cent.	$O_2 + N_2$, Per Cent.
Wood	51	6	43
Peat	58	6	36
Lignite	70	5	25

According to Muck, the average composition of peat is as follows:[2]

	Per Cent.
C	59
H_2	6
N_2	2
O_2	33

The following is the analysis of the ash:

	Per Cent.
Silica (SiO_2)	52.61
Aluminium oxide (Al_2O_3)	31.21
Ferric oxide (Fe_2O_3)	3.11
Calcium oxide (CaO)	3.03
Magnesium oxide (MgO)	0.08
Sodium oxide (Na_2O)	9.39
Potassium oxide (K_2O)	0.65
	100.08

[1] See "Heat Energy and Fuels," by Jüptner-Nagel, p. 142.

[2] Jüptner-Nagel, p. 160.

ANALYSIS OF GAS FROM A SAMPLE OF THE MATERIAL.

A portion of the material was dried at 100°, powdered and heated in a small, hard, glass test-tube, so arranged as to collect the gas over water.

After heating until practically all of the air was displaced, a sample of the gas was analyzed for carbon dioxide and found to contain 88 per cent. After further heating the per cent. of carbon dioxide fell to 74 per cent. The heating was continued until the gas was combustible, whereupon the analysis was as follows:

	Per Cent.
Carbon dioxide	19.61
Carbon monoxide	10.38
Hydrogen	63.85
Methane	5.19
C_nH_{2n} series	none

The oxides of carbon, hydrogen, and methane made up over 99 per cent. of the gas mixture at this stage of the destructive distillation, and it is to be noted that it contained a very large percentage of hydrogen; it burned with an almost colorless flame.

The gas was passed through a wash bottle containing water, some yellowish matter with tar-like odor was trapped in the wash bottle, and the wash water reacted slightly acid toward litmus.

It is well known that the quantity and composition of the various products obtained by destructive distillation depend not only upon the character of the raw material, but upon other factors, the most important of which is the gasifying temperature.

SOLUBILITY.

When the material is shaken up with water, a part of it apparently forms a dark-colored solution, which readily passed through the finest filters—so that chemists who made preliminary tests on it pronounced it "soluble in water." Further tests proved, however, that the matter is merely a suspension (a *suspensoid*), or a colloidal solution; it is precipitated by the addition of small quantities of various electrolytes; the precipitate is black, and can be collected on a filter and washed with water.

The following experiments were carried out:

1. A small sample of the material was shaken up with 100 c.c. of water in a tube 30 cm. long, and then set aside and observed from time to time for a period of nearly three months. A small portion of the solid matter (apparently mostly clay) settled on the bottom of the tube, but the solution was still dark brown, and when a small portion of it was treated with a few drops of hydrochloric acid a brown-black precipitate was formed and the supernatant liquid was practically colorless.

2. 0.5 g. of the moist material was shaken up with 300 c.c. of water, 20 drops of strong hydrochloric acid added, and the mixture heated to 60°. The resulting precipitate was allowed to settle and then filtered off. The filtrate was perfectly clear and almost colorless (slightly brownish); it was washed with hot water, and the filtrate evaporated to dryness. 8.05 per cent. of soluble matter was left behind, which was brownish.

Dean Magie examined a colloidal solution of the material under the microscope and he reports that the Brownian movements were conspicuous.

SOLUBILITY IN VARIOUS ORGANIC SOLVENTS.

To determine the solubility of the dried material in various organic solvents, tests were carried out in a Soxhlet extractor. In every case the weighed sample was tied up in filter paper and then enclosed in a porous cylinder.

1. A sample was extracted with petroleum ether for two hours. 0.55 per cent. went into solution. The same sample was then extracted with acetone for six hours. 1.36 per cent. dissolved, making a little less than 2 per cent. in all.

2. A second sample was extracted with methyl alcohol for six hours. 1.23 per cent. dissolved. The same sample was then extracted with chloroform for five hours. 0.9 per cent. dissolved.

3. Still another sample was extracted with carbon disulphide for six hours. 0.92 per cent. dissolved.

In every case the matter dissolving in organic solvents amounted to 1–2 per cent. (approximately), and it appeared to be *resinous* in character.

The experiments with the organic solvents prove that the material is not of the nature of asphalt minerals, etc.

TEST FOR CARBOHYDRATES.

One of the chemists who made a preliminary analysis of the material found that it reduced Fehling's solution to an extent corresponding to 8 per cent. of glucose. To find out whether the deposit contains carbohydrates the following test was made:

A sample of it was taken up with water, and a few drops of an alcoholic solution of α-naphthol and some strong sulphuric acid were added. No violet coloration was produced; but when the smallest piece of filter paper or an exceedingly small quantity of glucose was introduced along with the black material, and the α-naphthol test carried out, the violet coloration appeared promptly.

CONCLUSION.

My conclusion is that the carbonaceous part of this remarkable deposit is of vegetable origin. The vegetation may have grown in a swamp and been deposited *in situ* or it may have been washed into a basin or depression along with clay. No doubt the vegetable matter was steeped in water for long periods of time, thus undergoing thorough disintegration, the vegetable fiber having been more or less transformed chemically, and a colloid was formed.

In its chemical composition (excluding water and mineral matter) the deposit most resembles peat, but as to the manner in which it has been probably formed my colleague, Professor C. H. Smyth, has suggested that it is most like cannel coal.

Peat is the youngest member of the fossil fuels and is nearest wood in its chemical composition. It is vegetable matter that has undergone partial carbonization. The carbonization will be different if the vegetation is covered with water, and if it is isolated from the atmosphere by layers of clay.

In the younger coals there is mainly a formation of carbon dioxide as the vegetable matter undergoes transformation.

By the destructive distillation of wood much hydrogen is formed, and this is true in the case of peat.

By the destructive distillation of the black deposit, hydrogen and carbon dioxide are the principal gases evolved.

A quantitative analysis of the ash shows that it is primarily silicate of aluminium and sodium.

A microscopic examination of the ash showed that it is a finely divided material, and no indications of a diatomaceous earth were observed.

THE DISCOVERY OF PYRRHOTITE IN WISCONSIN, WITH A DISCUSSION OF ITS PROBABLE ORIGIN BY MAGMATIC DIFFERENTIATION.

RUFUS MATHER BAGG.

LOCATION.

About two and one half miles southeast of the town of Mountain, Wisconsin, in the northeast quarter of Section 13, Township 31, Range 16, occurs an interesting deposit of pyrrhotite. This mineral as far as we know has never been recorded as occurring in Wisconsin. Because of this fact and more especially because it seems to offer some evidence concerning the deposition of such masses by segregation coincident with magmatic cooling, we feel that it is worth describing.

GEOLOGY OF THE REGION.

Pre-Cambrian granite forms the "country rock" in the vicinity of Mountain and its glaciated surface outcrops in many places in the immediate neighborhood.

This pre-Cambrian granite 2½ miles from Mountain has been intersected by a strong basic dike belonging to the gabbro series, and the pyrrhotite mass occurs in this dike. In this vicinity the granite has lost its holocrystalline granitic structure and become very felsitic and fine-grained. It lacks the biotite, shows only a few scattered orthoclase crystals, and is itself cut by other felsitic acid eruptives, one of which is younger than the gabbro dike above referred to. The granite is probably Upper Huronian, since the Cambrian-Algonkian contact runs not far from this place, crossing the country about midway between Kingston and Breed. It is not necessary to suppose that these several eruptive types, including both acid and basic rocks, are separated by great time intervals, but it is probable that they represent equivalents to the iron-bearing Huronian series outcropping northeast along

the Wisconsin-Michigan boundary and in which commercial iron oxide ores are so remarkably developed. The gabbro dike carrying pyrrhotite trends north 20 to 25 degrees east (magnetic) and is of varying width of from 60 to 200 feet, but its walls are sharp and well defined, showing that the felsitic granite had cooled and fissured prior to the dike injection.

PYRRHOTITE.

Pyrrhotite is not mentioned in the Wisconsin Geological Survey Reports (Vols. I.–IV., 1873–1879), though pyrite is given in the "Catalog of Minerals," Vol. I., p. 313. The compiler, Professor Irving, makes, however, this significant statement regarding pyrite:

> "As singularly free from pyrite may be mentioned the rocks of the Keweenawan series in the vicinity of Lake Superior. While this mineral has in a few rare instances been noticed in little transverse veins, and *even in the mass of some diabases in this series*,[1] its almost universal absence from both eruptive and sedimentary members is very striking."

From the above it is evident that pyrrhotite in the Wisconsin gabbros was unknown. The Mountain pyrrhotite is massive, strongly magnetic, of typical bronze metallic luster, tarnishes readily and becomes iridescent and it is easily scratched with the knife. It cannot therefore be mistaken for pyrite, which is non-magnetic (magnetic only after heating), of bright yellow color and much harder. Pyrrhotite often carries nickel or cobalt and sometimes in commercial quantities as at Sudbury, Canada and at Lancaster Gap, Pa.

Analyses of this mineral at Sudbury give Fe, 56.39; S, 38.91; Ni, 4.66 per cent.

Analyses of this mineral at Lancaster Gap give Fe, 55.82; S, 38.59; Ni, 5. 99 per cent.

Three analyses of this mineral at Mountain, Wis., averaged Fe, 56.154; S, 43.846; Ni, none.

These analyses were made by Mr. H. T. Bennett of Lawrence College.

[1] The italics are ours.

ORIGIN OF THE WISCONSIN PYRRHOTITE.

There is strong evidence that the pyrrhotite deposit under discussion has been deposited contemporaneously with the enclosing basic dike. In the first place the mineral is quite fresh and unaltered close to the outcrop and there is no secondary enrichment at the surface. The alteration which has occurred has oxidized the crustal layer into the characteristic iron oxides, hematite and limonite, which coat the surface, but the solid pyrrhotite masses become richer (if anything) at a depth of eight feet below the surface. The only exploration work on this deposit consists of a vertical shaft ten feet deep, but it is enough in this case to reveal the character of the deposit. In the second place the mineral merges into the gabbro dike in somewhat indefinite lines and does not run in well-defined veins into the gabbro mass. I ought to state, however, that in the examination of this dike 200 feet east of the first outcrop tiny veinlets of this mineral impregnate the dike, but they might easily be due to segregation along minute shrinkage lines during the cooling of the mass. At any rate, the evidence seems to favor the segregation and differentiation of the pyrrhotite during the process of solidification. The third point bearing upon this is shown by the spheroidal shelly structure of the pyrrhotite mass near the surface outcrop where it is best exposed. This zonal differentiation reminds me of the so-called "diabase boulders" visible in the copper mine amygdaloidal masses in the Lake Superior Keweenaw Point region. In the Mohawk amygdaloid the hanging wall shows these diabase masses remarkably rounded as if they represented zonal weathering so characteristic of igneous masses of this type, but these masses are deep; those I examined were 900 feet below the surface and they were well within the diabase and formed the border of the copper bearing amygdaloid so that they serve as a guide to the limits of the ore bodies in this property. It may be argued that the analogy is not close but at any rate it is strongly suggestive as the rock types are not far apart. A view of the outcrop of pyrrhotite given below may help to make this point clear.

At the outcrop shown in the photograph on page 372, where the

exploratory shaft was sunk, the dike measures 41 feet in width, but it widens to the northeast and is nearly 200 feet wide within the next half mile. The "ore" shown in this shaft opening measures thirteen feet, but the curved differentiation lines suggest that this width would not be constant for any great depth. This may be, however, only the top of an immense "core" of ore, but it has the appearance at this outcrop of going down to con-

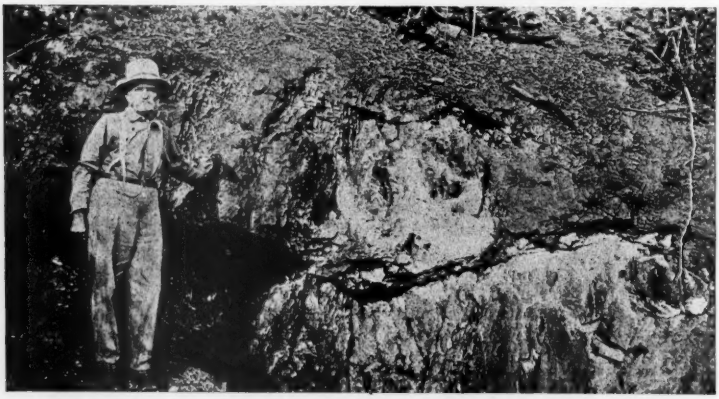

FIG. 30. Outcrop of pyrrhotite showing the differentiation lines between the "ore" and the enclosing "gabbro."

siderable depth, since the walls of the dike stand nearly vertical and the pyrrhotite is more massive and in larger development at the bottom of the shaft. If this was a deposit of the true vein type like that of Sudbury, Canada, this core-like mass should have better wall definition and not contain igneous rock material within its general mass. In fact this segregation at the outcrop is not so complete that the separation between the igneous magma and the pyrrhotite is definite, although as stated at a few feet below the surface solid masses of pure pyrrhotite can be taken out.

We shall consider from the above that the evidence of magmatic differentiation is sufficient to explain this deposit in question and that this is the only way in which this mineral could have been developed within the gabbro dike.

DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, Sheffield Scientific School of Yale University, New Haven, Conn. The full name of the author should be attached to all communications.

FIELD AND OFFICE METHODS IN THE PREPARATION OF GEOLOGICAL REPORTS.

THE PENFIELD PROTRACTOR.[1]

Sir: Some geologists may care to learn of a simple instrument which I have come to regard as indispensable in field work, but which seems less widely known than it deserves. This is the protractor and goniometer designed by the late S. L. Penfield and made by E. L. Washburn & Co., New Haven (see Fig. 3). The body of the instrument is an oblong piece of cardboard on which is engraved a graduated semicircle and, on one edge, a millimeter scale; to this is attached a celluloid arm moving about a pivot at the center of the semicircle. Personally I find that, considered merely as a protractor, this instrument is much more convenient than celluloid protractors of the ordinary types. One point of superiority, due to the body's having four straight edges, is ease of orientation, and this may even be increased by ruling the face as shown in the figure. In protracting a strike observation or a compass-sight on the map, one of the edges or ruled lines is made to coincide approximately with a meridian or parallel, while the arm, previously set at the proper angle, is made to pass through the point of observation, both objects being accomplished simultaneously by slight movements which quickly become instinctive.

[1] Published by permission of the Director of the U. S. Geological Survey.

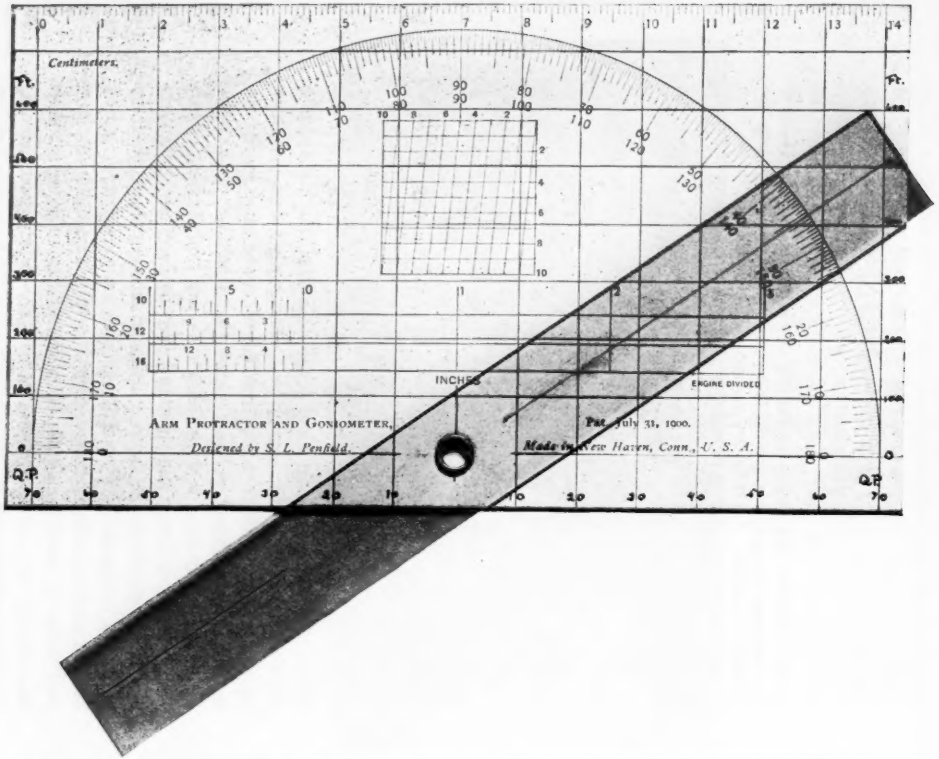

FIG. 31. Penfield protractor modified for field use. Photograph by U. S. Geological Survey.

The convenience of having both protractor and scale combined in a single instrument so light and flat as to be carried easily between the leaves of a notebook is obvious. It happens, moreover, that the millimeter interval of the graduation on the edge, though chosen without reference to the common map scales, is about as good for certain purposes of the geologist as any that could be used. On the scale of 1/62500 a mile is represented by a little less than 26 mm., so that 1 mm. may be taken as practically equivalent to 200 feet in laying off distances estimated or paced. The instrument is perhaps most useful, however, in platting foot-traverses; and its wider use may, therefore, increase the availability of a field method which can sometimes be employed with advantage by almost any geologist.

This method, in which distances are measured by pacing and directions determined by compass, is too well known to require description.[1] It is especially convenient in work where no good base-map is available, but where land corners, or numerous locations intersected by a topographer, may be used as tie points. The ordinary unit of measurement in traversing is the "quadruple pace," about 1/500 of a mile for the average man. Perhaps the most generally convenient scale is that of 1 mile = 2 inches, this being, for example, the scale of the land office plats and of the township maps filed with the land classification board of the Survey, and consequently that on which most of the classification field work is platted. Now, on this scale, ten of the usual quadruple paces are represented by one millimeter with an accuracy quite commensurate to that of the method, for which, therefore, no unit of division could be more suitable.

The protractor finds a special use in the case, occurring often in a rugged country, when horizontal distance is best reckoned by solving the equation $d = h \tan \alpha$, where d the distance, h the elevation determined barometrically, and α the angle of slope. With its body ruled in squares, the instrument gives without the draw-

[1] See Bailey Willis, "Graphic Notes for Areal Geology," *Bull. Geol. Soc. America*, Vol. 2, 1890, p. 177, and "Hand-book for Field Geologists in the U. S. Geol. Survey," 1908, p. 53.

FIG. 31. Penfield protractor modified for field use. Photograph by U. S. Geological Survey.

ing of a diagram a graphic solution[1] whose result, being in feet, is converted to quadruple paces by dividing by the number of feet in a quadruple pace (10.56). The difference between this figure and 10 is negligible in most cases. The result in quadruple paces is given directly, however, if the shorter cross-lines are ruled on the card at an interval of 1 cm., and the long ones at an interval of 10 cm. ÷ 10.65 = 0.947 cm. Then, if 1 cm. is taken for this purpose to represent 10 q.p., 0.947 cm. represents 100 feet. For example, if $\alpha = 34\frac{1}{2}°$ and $h = 330$ feet, as in Fig. 31, $d = 46$ q.p., represented on the map by 4.6 mm. Whatever the length of the user's average pace, the ruling spaced as shown gives the proper distance on the scale of 5.0 cm. = 500 q.p. The difference, usually slight, between this scale and that of 2 inches = 1 mile can be allowed for in the adjustment always necessitated by the imperfect accuracy of the method.

F. C. CALKINS.

SOME SUGGESTIONS AS TO FIELD METHODS.

Sir: Every well-trained geologist will recognize that field methods employed in one particular line of investigation may not apply in another; that the best mode of procedure, for example, in a study of ore deposits or the geology of an igneous area cannot be followed even in a general way in investigations on oil and gas. Those methods described in this article, which are in common use by the Oklahoma Geological Survey, have been in part adopted from other surveys and in part devised to meet those problems which may be regarded as more or less peculiar to Oklahoma geology.

Individual Outfit.—Beyond question the success of field work depends much on what may be termed the outfit of the individual geologist, that is, his instruments, notebooks, maps, carrying cases, pencils, rules, and mode of travel.

[1] For this purpose the line along the middle of the arm should be continuous. It was so in the instruments formerly made, but the recent ones have merely two short scratches at the ends. The change apparently had the shortsighted object of concealing the slight inaccuracy of centering, which is apparently unavoidable; this inaccuracy, however, should of course be evident in order that it may be allowed for.

In much of this state a clinometer is a useless instrument. The strata are essentially horizontal, the dip, if any, being less than 1°. Instead of the clinometer the Brunton compass is used. The advantage derived from this instrument is that it serves at once as compass, level, and clinometer if this latter is needed. Experience has shown, however, that the beginner can get better results with an ordinary hand level than with a Brunton because a certain technique is necessary to get good results with this latter instrument.

The Oklahoma Geological Survey uses three kinds of notebooks of the same form and pattern as[1] used by the United States Survey. The loose-leaf book is used to record detailed data on various formations, localities, or economic deposits as the case may be. In office, the material can be then readily assembled. The two forms of bound notebooks serve various purposes. In oil and gas work I use the smaller book as a container for final field map, and for profiles as noted below. In other lines of work the chief of party is given the privilege of choosing his own book and some prefer the larger bound book on the ground that a larger portion of the map can be presented to the eye. It must be admitted that this has certain obvious advantages.

Each worker in the field is provided with two maps. Each map is cut into sections, the number of which varies according to the size and shape of the map. If the 30 minute topographic sheet is employed, two copies are cut into nine sections each along the ten minute lines. One set of these sections is then mounted on muslin and used as a travel map. On it the observer may make preliminary sketches or notes, always using it as a guide and for rough work. The other set of sections is numbered beginning with the northeast corner of the sheet and following the plan of numbering sections in the land survey. The several sections are then pasted by the corners into the notebook and are to contain the observer's final contact lines. The advantage of pasting by the corners is to render removal easy in case such is

[1] 9-911, 9-927, and the loose-leaf books.

necessary in the office. Thus protected in the notebook, the map is not soiled or damaged. As work progresses on this areal map the formations are "colored in," the possibility of error or omission being thus materially lessened.

If several workers are engaged in mapping a given area a single final map is made as the work progresses, lest some areas be neglected and others covered twice. If only one or two workers are engaged in a given locality the preparation of the final map can be deferred till office work is begun. Then the lines on the several sections of map are rapidly and accurately transferred to a final sheet in a simple manner: A plate glass about three feet square is supported on two opposite sides. A strong electric lamp is placed beneath the plate glass and the room then darkened. The sections of map to be copied are placed one by one on the glass and directly over the lamp. The final map is superposed on each section in succession and the contact lines traced with pencil. The rest is simple.

Method of carrying notebooks is of prime importance. Too often slouchy, careless work can be attributed to the fact that the worker suffers himself to be impeded by his instruments and bags. In my own work, I have found that the best carrying device for notebook is a stiff leather case large enough for two notebooks and the travel map. This leather case is then attached to the person by the belt. On the interior of such case can be fitted a small semicircular pocket for the protractor. On the outside are pockets for pencils, fountain pen, and rule. The case is closed by a flap which is only a prolongation of that side of the case that is next the person, turned outward and fastened down by a button such as are used on ordinary kid gloves. The whole is a device which is convenient, light, easily manipulated, and never an impediment.

The rules or scales used by this survey are made to order. They are of maple, flat on one side and beveled on both edges on the other side. One edge is graduated to miles, the other to feet, both being adapted to a map on a scale of 1:125,000. The worker is not permitted in detailed work to estimate distances on the map but measures directly with the rule.

Compass, hand level, and similar instruments are carried in leather cases attached to the belt, while the hammer is carried in a loop in the belt. Thus accoutred the worker has at all times all necessary instruments ready at hand, is not impeded in walking, or stooping, and has the hands free.

Methods of Travel.—Experience in my own work and in reviewing and revising the work of others has taught me that comfortable methods of travel—carriage, cart, or other vehicle—are decidedly detrimental to good field work. This has been found to be true especially with beginners. It too often happens that all or at least most of the observations made in areal, structural and some kinds of economic geology are made along roads and highways where travel is easy. Beginners and others seem to meet insurmountable difficulties in persuading themselves that public roads are not necessarily laid out along lines which offer the best data for the elucidation of geology. In work covering the eastern half of this state, the saddle horse is by all means the best means of conveyance. Travel by this method enables the worker to go wherever he desires regardless of roads or their condition. An animal well trained can travel with comparative ease all but the very roughest portions of the state. In the western part of Oklahoma were there are wide stretches of level prairie, the motor cycle is used to great advantage and economically where a single worker is concerned. It is planned to use the motor cycle more extensively as the work progresses in this part of the state. If more than one worker is to be accommodated in this region the method of travel is determined by the sum total of conditions. In general workers are urged and even instructed to travel on foot as much as possible and foot work has been found in all respects superior to any other.

Methods of Location.—Where the territory is laid off in sections methods of location can obviously be more simple than elsewhere. This survey uses the section corner as the starting point in practically all cases, there being very few instances where these corners cannot be determined with a reasonable degree of accuracy at least. Measurements are made generally along section

lines. In travelling on foot or in saddle one may take 1,000 double paces to the mile and be always within the limits of accuracy permissible on the topographic sheet. Ordinarily the geologist can, with a little practice, step 31 inches. Counting for only the right or the left foot, 1,000 paces is almost a mile. The ordinary horse will step about the same distance. If a vehicle is used the revolutions of the front wheel can be counted.

To count paces or revolutions the simple hand pace counter is employed. Counting mentally is not only too laborious for the worker but is a too frequent source of error. The pace counter is used in preference to a cyclometer in counting revolutions because it is readily set, unnecessary mental work being thus avoided and at the same time the numbers are always visible, which is not necessarily true of a cyclometer on dusty or muddy roads.

Measurement being made along a section line in a given direction from a section corner, the observer always has his exact location. In most cases it will be necessary for the observer to visit the interior of the section. In so doing the pace can be made along the midsection line from the "quarter corner." In thus following cardinal directions the geologist reaches a high degree of accuracy in his work which would be hardly possible if traverse be made along random lines.

Having in this manner obtained his location, the observer measures his distance on the map with the scale above described. In detailed work no worker is permitted to estimate distances in nature or on map, and it is believed that many errors and inaccuracies in areal work are due to such estimates.

Determination of Structure.—Detailed structural work has been carried on practically only in relation to the accumulation of oil and gas. This amounts to saying that structural work is concerned with the detection of anticlines. In all of the territory studied in this manner, the strata ordinarily dip gently westward at a rate of approximately 30 feet to the mile and it hence follows that the presence of an east dip is proof of anticline. But several of the anticlines already worked out run east-west. Moreover,

it is practically certain that in at least some of the oil-producing areas of the state the structure influencing accumulation is a northward-dipping monocline. Dome structure is also common. But whatever the structure the dip is usually very gentle, 50 feet to the mile being rather steep. The clinometer, hand level, or Brunton compass is worthless to determine accurately such dip, and resort is had to another method. If the altitudes of section corners are not known they are determined. From these known elevations, aneroid profiles are made along all section lines where contacts of any sort whatsoever are to be had, and the elevations of contacts are thus ascertained. The thicknesses of the several formations being known, the elevation of an easily recognizable horizon can be calculated. If the aneroid is found to be in error when a section corner or other point of known elevation is reached a correction is made proportional to the length of the profile. The elevation of a given horizon can thus be determined with a reasonable degree of accuracy at a large number of points. These elevations are plotted and contour lines are then drawn on the horizon. The structure then becomes at once apparent (see Bulletin No. 16 of this survey).

Experience has shown that delicate structure such as that prevailing in our oil fields can be determined with a reasonable degree of accuracy if the elevations of alternate section corners are known—that an aneroid profile can be carried two miles. It is not profitable to attempt to make aneroid readings do more than this. The uncertainty is too great.

Personally I think it will prove to be profitable in the long run to determine the elevations of all contacts by alidade and plane table, especially in open country where fairly long shots can be made. Aneroid profiles, however, if carefully and properly made have the added value of showing thicknesses and character of all strata encountered. The value of such data is very high in office work.

D. W. Ohern.

SOME NOTES ON EQUIPMENT.

Sir: My operations are mostly confined to somewhat inaccessible and but imperfectly charted districts; and much of my available time is often taken up by the preparation of a topographical map to serve as the base for geological work.

My outfit for reconnaissance comprises a sketching board, a 3-chain steel tape, an aneroid, and an Abney level and prismatic compass combined. The sketching board, a modification of that used by cavalry officers, is 11 in. by 17 in. in area and is made of three-ply veneering furniture boards ⅛ in. thick, stiffened by two longitudinal pieces, to which are pinned leather holders for pencils and scales; near either end are attached leather loops, 3 and 4 in. in diameter, as arm supports; and the protractor slips into a leather pouch with push button at one end. As the board is attached to the forearm leaving the hand free it can be carried without inconvenience by coach, on horseback, or on foot. It is perhaps slightly on the large size for complete comfort on a restive horse, and in future it is my intention to keep the above board for foot work, using a smaller one on horseback. For attaching the paper or cloth to the board, drawing pins were first used, but they damage both paper and board and recourse was had to plain straight spring bicycle clips; but these were so frequently lost that ordinary spring paper clips have been substituted.

I am aware that the "Batson" sketching case advertised by Messrs. Gurley, of Troy, New York, embodies a number of desirable features, including a movable graduated circle and alidade, but the small size of the instrument must restrict its use. If made in larger sizes and fitted with a small prismatic compass the "Batson" should be a very useful instrument.

For field work if maps are available they are cut into sections a little smaller than the board and for new work coördinate paper is used the full size of the board, so that the separate sheets will overlap and that along the edges will show on two sheets. Thus when one sheet is complete or when the traverse passes beyond its limits the stations on the edge are traced through on to the new sheet and the work continued by ordinary topographic methods—the method of intersections by bearings from a known base being

preferred where practicable (as I am usually without an assistant). The board has proved of use underground as well as on the surface, where a modern plane-table is not available or when conditions do not allow of its employment.

Field notes are made in pencil but they are inked in the following night with water-proof India ink, the standard colors being used for the different features. The applicability of a portable barograph to reconnaissance field work is within the realms of probability, but the minutes of the graph is against its practical employment. This might be rectified by employing transparent films and enlarging photographically.

My aneroid is a 3-in. Short and Mason, provided with vernier and reading to single feet. The instrumental error is determined from time to time by the nearest railway levels, and necessary corrections, if any, have then to be made to all readings. During the progress of field work the instrument is read as often as time will permit but always immediately after reaching and immediately before leaving stations, so that the diurnal variation in atmospheric pressure may be allowed. The contours of the ground and country in the vicinity are then sketched in and the corrected elevation of the station shown. The substitution of clips for the buckles usually supplied on the cases of portable scientific instruments saves much time and worry, and the little toothed clips sold on light riding boots are ideal for the purpose.

When rapid journeys have to be made the elevations are subsequently plotted, as read, on coördinate paper and the correction for rise or fall of the barometer during the traverses are estimated by graphic methods, any errors of closure being distributed.

LIONEL C. BALL.

BRISBANE, QUEENSLAND.

Sir: In contributing a few suggestions to the present discussion regarding field methods in geological work, my remarks should be prefaced by the statement that what work I have been called upon to do in this line has been altogether in connection with mining enterprise. It is further likely that the equipment used (as being easily available) may have precluded that nicety

of detail and choice of methods obtained in the ranks of the U. S. G. S. My work, also, has been limited to rough country—*new* country, so to speak, with few roads, or even trails, and such few time-savers as I may be able to suggest are functions of this particular condition. Freely offering for your use a few methods which have appealed to me, I shall cover them in as brief a manner as possible.

Many workers in virgin country have been somewhat hampered, at the very outset, from the lack of *maps*. In many cases none are available, in most cases such as may be at hand are inaccurate, and (we may whisper it safely) cases have occurred in which the Survey maps have shown a lack of the most scrupulous exactness. Supposing a good map to constitute the first essential (always remembering the "new," pathless, rough country with which we are dealing) my experience leads me to prefer the stadia survey to any other method possible. Setting aside the immense saving in time (although this is frequently of the first importance) I base my idea upon the question of accuracy. Lacking a somewhat continuous and expert acquaintance in either chaining or pacing, in a rough country I consider both not only unnecessarily tedious but, as compared with stadia work (where the onus lays more directly in the hands of the engineer himself), relatively inaccurate. Using a small Wittstock mining transit and a stadia-rod, homemade and adapted to my own vision, I have been able to do some work in this line which has been fairly acceptable; and, as a matter of fact, remembering the advice of my old friend Dr. V. T. McGillycuddy concerning his work on the first (and one may say the *only*) map of the Black Hills (made in the course of the Newton & Jenney Survey), I have twice undertaken work of this sort *on horseback*, with a resulting saving of time quite remarkable, and, apparently, no great loss in accuracy. A survey of this sort, tied to some established monument if one is available, or to some prominent natural monument, with triangulation of important points, will furnish a sound basis for a good map, without which all further work lacks value. One becomes used to a small pocket note-book, as a function of

convenience; but, in work of the above description, a book at least 10 × 12 inches in size, with good stiff covers, should be used. In this a continuous sketch of the survey can be carried along with as much nicety as the skill of the engineer will permit, and much important data can be noted in the first traverse.

In the above preliminary work, as well as in the work which follows, the writer's experience leads him to lay stress upon the character of the instruments used (their accuracy being provided for), the general equipment and the methods employed, than upon the constant necessity for checking and re-checking all data. However deeply the engineer's mind may be engaged in the work at hand, a very limited experience will emphasize the absolute necessity for checking his own work and for making the most careful notes; how much more necessary then is the close scrutiny of the work of his assistants, whose ability may or may not be sufficient, and whose interest may or may not be deeply engaged in the work at hand.

In connection with this matter of checking and re-checking figures, something should be emphasized concerning the necessary care in accumulating general data. In general, if an engineer wishes to be sure of his data, as forming a sound basis for his final conclusions, his only safe plan is to *take them himself*. If he is unable to do so, an element of uncertainty is unavoidably introduced, which *may*, later, cause him some dissatisfaction. Rock- and ore-samples should, at least, be taken under his direct observation; preferably with his own hands; and immediately labelled by himself in a thoroughly complete and safe manner. The method used is frequently a function of the conditions involved; but security, completeness of record and fixity of labels are of vital importance. Local reports are of value only as they may refer to some matter which he might overlook; they must be confirmed by his own eyes in all cases where they are of sufficient importance to be used at all. It should also be remembered that stratigraphic records, as obtained from shaft and drill-core data, *may* at times lack the necessary degree of accuracy.

There is so much in this subject which might be said, and pos-

sibly to someone's advantage, that there is great danger of prolixity. The writer, therefore, limits his expression to those few points which he has mentioned above, and which first occurred to his mind. In closing, he ventures one further suggestion: Geological investigations are either of a special or general character. This condition at once limits and decides many factors in the equipment and methods to be used. In any case, if the time factor is of importance, experience leads one to adopt a busy man's method, to wit: If the work is "crowding" the engineer, he will find it of advantage to take upon his hands and brain that item of the work which seems *most important;* shutting his mind, as far as possible, to all other items till this is finished; and so on.

F. C. SMITH.

SOME METHODS OF GEOLOGIC FIELD WORK.

Sir: The methods of geologic field work employed by the parties in which the writer has worked for a number of seasons are not new, but details of several features that you indicate in your letter will be given.

Most of the work has been done in mining districts that had not been previously mapped; consequently the topographic and geologic maps are made by the same party. Though this method has obvious disadvantages, there is often much gained by having the topographic map made by men who have a knowledge of geology. While the topographers are not expected to delay the topographic mapping by taking geologic notes, tracing contacts, etc., they often facilitate the geologic mapping by indicating on the lines of their traverse a dike or contact. This can frequently be done, especially at a plane-table station, without loss of time, and done accurately. In addition to mapping the topography and all the culture that ordinarily appears on a topographic map, the topographers locate, by plane-table methods, all shafts, tunnel portals, quarries, and prospects. Frequently also landmarks are located, such as a lone tree, roofless cabin, flume, prominent outcrop.

The topographic map is traced on stout tracing paper in sec-

tions 12 by 12 inches, a size which readily folds into a notebook. To the points mentioned the geology is tied by compass bearings and pacing, or by intersection or resection by means of a Brunton compass and xylonite protractor. As a result of having numerous points previously located by the topographers, long sights with the compass are avoided. The geology is thus mapped nearly as accurately as it would be were a plane table used instead of compass and protractor. Since the topographic map will subsequently be used, ordinarily, by one who wishes to locate himself in the field, drainage lines, roads, trails, peaks, etc., are given preference in the geologic mapping if there is a discrepancy between location with reference to these and location by compass bearings. In other words, the topographic map is assumed to be correct. If errors exist in this, geology referred to points or features wrongly placed will be in error.

Geologic boundaries, dikes, faults, veins, and horizon markers are indicated on the map with a sharp pencil and labeled. Instead of colors or patterns to represent country rock, abbreviations are used—*gn* for gneiss, *gr* for granite, *qz* for quartzite, etc. Specimens are numbered consecutively, and a point (.) with an index number placed on the map at the exact spot from which the specimen came, unless it should be taken from a mine or prospect whose symbol takes the place of the point. The notebook entry would contain the station number, followed by the specimen number and whatever explanatory notes may seem desirable. Index or station numbers are also listed consecutively and obviously after the first few entries are made, specimen number and index number will be different. We use fairly heavy paper bags for wrapping specimens; the 5-pound sack of the grocery stores is perhaps the most suitable. The specimen number (prefixed by the collector's initial if more than one are doing geologic work) is marked on the outside of the sack with a soft pencil and the specimen placed in the sack, which is then wrapped around the specimen. By this means the specimens are always ready for packing for shipment without further wrapping—except fragile mineral and fossil specimens—and there is no danger of their

being separated from their proper numbers. As a rule, we do not stop to trim specimens in the field. Instead, two or three promising pieces of each sample are taken to be trimmed at camp on a rainy day or after the collections reach the laboratory. Chips for thin sections are selected at the time of trimming.

The traverse methods vary from time to time according to the complexity of the geology, the relief, number of roads, etc. The first traverses are ordinarily run where there seems to be the best chance to get a general idea of the geology, either along a ridge, over a road or trail, or down a gulch. Generally the same attention is paid to details on the first traverses as later in order to obviate a retraverse, but side trips to follow out contacts, dikes, etc., are avoided. These features are platted on the map where they are followed or crossed by the traverse line. They are subsequently extended by parallel traverses or by following each one individually according to the necessities of each case. Obviously the accurate mapping of an irregular contact between a stock and older rock requires numerous locations on the contact and often a continuous traverse, while a nearly straight and vertical dike may be accurately mapped by the location of fewer points.

Everything on the geologic map—boundaries, dips and strikes, faults, symbols, index numbers, etc.—is inked in with waterproof ink at intervals of a few days each, in order to make it permanent. Colored ink is used to prevent confusion of geologic and topographic lines. To obviate the possibility of a gap in the map, before breaking camp all the principal geologic boundaries are transferred to a sheet of tracing linen, together with as much detail as seems necessary. This requires but little time, and the map thus made shows the trend of the geology and not infrequently aids in planning the future work.

The notebook record includes: megascopic petrography; physiographic notes; dips and strikes; notes on metamorphism, faults, veins, ores and ore bodies, minerals, methods of mining, mine equipment, and anything else that may enter into a geologic report insofar as it may be determined in the field. Memory is not trusted. Ordinarily, on the first examination of a formation or

rock, a rather full description is written. On further examination of the same unit in other localities, only those features are noted which were not seen in the first exposure.

R. D. CRAWFORD.

A METHOD OF GEOLOGIC MAPPING AND NOTE TAKING.

Sir: The method of note taking and map record which I use in geologic field work is probably not materially different from that in use by many other geologists, but since I find it so satisfactory for the class of work in which I am engaged, I briefly present its somewhat distinctive points. I have used it mainly in areal surveys in the Appalachian region for folio publication, but it is just as applicable with certain modifications to other classes of detailed surveys in rocks of folded or complicated structure, provided there is available an accurate topographic map for a base.

For convenience in carrying in the pocket or specimen bag I have two maps of the area dissected and mounted so that they will fold to go inside the cover of a field note book. An ordinary topographic atlas sheet of the Survey can be dissected either into 9 parts, along two north-south and two east-west lines, or into 8 parts along a medial north-south line and four east-west lines, which, when mounted, will fold so as to fit in the $5'' \times 8\frac{1}{2}''$ note book generally used in the Survey. This sized book fits snugly into the side pockets of an ordinary coat. Preferably the book should open at the end, for the reason that the maps fit it better than a book that opens at the side where the binding edge reduces the available width, already limited by the size of the pocket it is to fit, whereas the length is not so limited. I find also that I can take notes more easily in a book of this type. The purpose of two dissected maps is to keep the field observations distinct from reference numbers, specimen numbers, and topographic corrections. On one sheet, which may be referred to as the Record Map, the observed strike and dip, if the rock is bedded, are graphically indicated at the point of observation, accompanied by an abbreviated description of the rock. The small space available for such notes requires the very finest writing and shortest abbre-

viations for most of the words. Thus Tk R ss, is used for thick red sandstone. To avoid obliteration these notes are inked at night, which should be done with a very fine pen and by the aid of a hand lens for satisfactory results. The boundary lines, so far as they can be observed, are also drawn on this map in the field, and at night are transferred to an office progress map on which the formations are shown in colors. I shall not discuss the matter of determining the units to be mapped nor the care that should be exercised in locating the boundaries and adjusting them to the topography, for these are factors that pertain to all methods.

The limited space in which a description of an outcrop can be written on the map makes it necessary to keep a record of measured sections, observed structural relations, and details of rock characteristics in a notebook. These notes may consist of only such details of isolated observations made during the day as seem of sufficient importance to demand a lengthy description, but I prefer to keep a somewhat complete descriptive account of the route of travel, as I find that it better recalls the observations to my mind in after years and aids in finding locality numbers on the map. The ordinary record consists of an account of the character of the rock, its attitude, relations, extent, and such details as are distinctive of each outcrop, the amount of description depending on whether there may be doubt as to the horizon or the structure. In this connection, inferred relations must be carefully distinguished from observed facts. In many cases this record conveniently takes the form of a profile section, which may be either carefully measured for the determination of thicknesses or only roughly platted to serve as a descriptive account.

To tie this notebook account to the map a system of consecutive reference letters and numbers is used, the figures being placed at the point of observation on the other dissected or locality map. Beginning with A1, the numbers run up to A99, and then B1 to B99, etc., thus avoiding figures of over three units. These are generally placed at points requiring detailed description, but should be at short enough intervals to mark the route travelled.

The description of a locality indicated by a number on the map can easily be found in the notebook, for the locality numbers are recorded there alphabetically and numerically, but to find a certain locality number on the map from a reference in the notebook is not so simple, as the numbers have no order on the map except as they follow the routes of travel. Writing the notes in the form of a description of the route, therefore, materially aids in tracing the locality on the map. The specimens collected are numbered consecutively from 1 up, and are marked on the locality map, where they are inked at night in red or some other distinctive color. On this map are also indicated the corrections to topography sketched in the field.

When following roads, with an accurate detailed map in hand, it is generally not necessary to make a foot traverse to locate one's position, but where traverses are necessary they can be platted either in the notebook, or, preferably, on an enlarged photograph of the map. I generally have made a photograph of selected parts of the map, usually the more mountainous areas where foot traverses will probably be necessary and where the structure is likely to be complicated, enlarging the scale at least 4 times. On such a large scale map the notes can be more complete and there is not so much need of the notebook records. The objections to this large scale for the whole map are that for the best results one needs a more comprehensive view than can be had from the small area represented on the section of a sheet the size of page; that one is continually passing out of the small area represented on a section of the map, necessitating the frequent shifting of the map sections; and that the bulk of the dissected map is too great for convenient carrying in the notebook.

The area to be mapped is covered as far as possible by traverses along roads that cross the trend of the structure, at intervals of one or two miles, the boundaries being sketched to conform to the topography on either side of the traverse as far as can be seen or reasonably assumed. This is supplemented by foot traverses between roads that are too far apart to give satisfactory control for the drawing of the boundaries, and also to all other points of

doubt not on the roads. The amount of foot-traversing between roads depends on the frequency of the roads, the regularity and continuity of the structures, and the assistance furnished by topographic features in tracing the boundaries.

The advantage of the above described method is that one not only has detailed descriptions in his notebook of observations, accurately tied to the map by means of the locality figures, but he also has before him a graphic presentation of the strike and dip of the beds in their correct positions, so that he can note their continuity and better comprehend their structure and other relations. The folded map can be spread open so that the whole area can be viewed at a glance and the relation of a specific feature or structure to the rest of the area can be studied, which cannot be done so readily where the observations are not placed on the map, or where pieces of the map are pasted on different pages of a notebook, or where the scale of the map has been so enlarged that the whole map becomes too cumbersome to handle. It is recognized that in its application to other regions having different geologic conditions, the method will require some modification, as in some cases the map records will consist chiefly of geologic boundaries with few strikes and dips and brief descriptions hardly requiring a notebook, while in others the descriptions may be so complex as to require detailed book notes and permit of few map references.

U. S. Geological Survey. George W. Stose.

DISCUSSION OF PAPER BY J. D. IRVING.

Sir: A few points open to discussion occurred to me while reading the recent article by J. D. Irving, on the "Substructure of Geologic Reports," and the following notes, although mainly expressions of opinion, may be of service:

The suggestion (page 72) of having an assistant select one's outfit from a previously prepared list seems unwise. This is too important a matter and should be done by the geologist himself, just as a geologist should examine an outcrop himself, if possible, and not delegate this work to an assistant equipped with a list of previously prepared questions.

In regard to collecting records (page 75) the point is not brought out that many times the taking out of a note-book, etc., is sufficient to make one's guide or informer stop talking and that consequently many facts must be retained mentally until the geologist is by himself. This is particularly true in work on ore deposits.

Personally I don't like the use of abbreviations because (1) they don't save much time in the field—as a test I find I can write "sandstone" twenty times in a minute and "SS." less than sixty times a minute; (2) the full word is less likely to be misread than the abbreviation; (3) the full word is more easily caught by the eye in scanning a page of notes; (4) the key to the abbreviation may be lost.

The point about F.R. (Funny rock) is, of course, well taken, but its absurdity is a little over emphasized if the criticism is applied to the use of what may be called colloquial field names. I firmly believe in such names; first, because they are useful; and second, because their change to the petrographically determined name is more readily accomplished than the correction of a misused technical name, especially when in the same region there are rocks to which the misused name correctly applies. It is almost inconceivable that the geologist on first using the colloquial term should not have entered in his note-book something of this sort: "Locality ——— 2 feet, dark aphanitic dike rock, same as specimen ———, with peculiar bubbly weathered surface, noted on map as Bubbly trap."

What a geologist wants to know is *all* about an ore body, etc. Therefore origin *per se* is not always the question that overshadows all others. Origin is enormously important because so many deductions are based on its determination, but unless the term is extended to cover many other things, will knowledge of the origin fill all practical and theoretical needs? I doubt whether a client would be satisfied with a report that a certain ore body was formed by metasomatic processes.

The discussion of work in mapped areas seems too incomplete and this appears at many places; for instance, on page 78 under

the heading "horizontal measurements" no mention is made of time traverses or boat traverses. The time traverse is extremely important, not only in wild regions but also in places where a map is available. In an unstudied region the statement that "a massive limestone outcropped six days' journey upstream" would be of much assistance, and such geographic facts as that "20 days upstream there was a portage to the west which the natives crossed in 2 days" would save many miles of exploration and would be of service in preparing plans and equipment.

Regarding the more exact use of the time traverse, a route map made by C. E. Giffin using only time and compass for distances and bearings and made from a canoe travelling six miles an hour for an air-line distance of about 75 miles or probably 150 miles by river, checked by astronomic observations at both ends of the traverse had a closing error of less than one mile. On this same trip geologic notes were recorded in time travelled, and little trouble was found in connecting the geologic notes and topographic map, though I will admit that in this part of the trip few exact geologic boundaries were drawn.

In many places where a map is not at hand, though a map may ultimately be available, a record of time and approximate direction of travel is useful. Thus, in areas where continuous geologic mapping is not necessary frequently much time and labor may be saved by travelling for a known period and then, where outcrops were numerous or facts of geologic significance secured, starting a foot-traverse map. Care should be taken to include in this map some point that would be subsequently recognizable from the topographic map that later will be available. The traverse might again be dropped and the time recorded until another known point was reached or a new traverse started. This sort of mapping is commonly very useful when *en route* to a mining property where a specific examination is to be made. Time traverses are also useful in mapping the geology along roads. In this case the time of leaving a mapped location, such as a road intersection, is noted and the time that elapses between various observations of features along the way recorded as well

as the length of time to the next recognizably mapped locality. Of course, it is hardly necessary to state that only actual elapsed time of travel is considered. The other measurements for boat trips, such as canoe logs, should be noted.

The suggestion (page 87) for the use of letters with subscript figures seems undesirable. Many geologists spend a hundred days or more in the field and therefore would use the letters over four times, necessitating the addition of a further tag. Furthermore, the letter serves very little use as the subscript figures give nearly as good cross reference to the note-book if the subscript locality numbers are assigned consecutively. If a coordinate system is used in recording, the use of letters and subscripts for other things is likely to cause confusion, as IIC1 may be the coordinate of locality IIIG4, obviously an undesirable combination.

The suggestion on page 95 to make specimen numbers stand out plainly is useful, but may be advantageously extended by the use of colored inks. On return to the office the main subject headings, such as locality numbers, specimen numbers, photograph numbers, general geology, economic geology, etc., are assigned distinctive colors; the facts bearing on each subject are underscored with the appropriate colored ink, or, where these notes are voluminous, a colored ink line is made in the margin. This system was subsequently abandoned in favor of card indexing the notes so that the cards could be grouped together as desired. The difficulty of making several cards for the same note is obviated by filing the card under the first subject that will be treated in the report, and then successively returning it to a place under subjects to be treated later in the report. Thus a description of a certain outcrop might be used in a section on general topography, in the description of the general geology, in the description of the detailed geology, in the part on historical geology, and in the section treating of the ore deposits, etc. Such a multiple use, however, is rare as, so far as possible, only a single subject report a card.

Photographs and sketches, although very important, are prac-

tically unmentioned. Descriptions are weak as compared with really illustrative pictures, and the geologist should constantly strive to get good views of the rocks, topography, and location of important features. Even though pictures are not to be used for reproduction they are extremely valuable in refreshing the writer's memory and in giving an adequate perspective to features that in detailed examination may have been seen at too close range. With the development of photo-topographic methods even geologic boundaries under certain conditions may be determined with a fair degree of precision from pictures. Field sketches are almost as important as photographs and if drawn with care take the place of pages of note-book description. These sketches should represent not only profiles and maps but perspective views as well.

The value of rough sketch maps for note-book records should be emphasized. Even though the directions and distances are laid down on these maps by eye, this graphic method is advantageous because any scale may be adopted so that plenty of paper is available for recording observations and so that records can be tied directly to the features to which they apply. Many times rough sketches would decrease the errors in recording bearings, for the geologist would see at a glance the direction in which the symbol should point. Furthermore, the attempt to draw an object requires more careful observation because in a sketch any missing features become more apparent than in written notes.

The coördinate system of note recording is open to the following objections—first, it takes considerable extra time to work out; second, it does not afford natural units such as formations or geographic areas recognizable in the field; third, it usually requires putting a location spot with or without a number on the map and is therefore the same as the uncoördinated system plus the coördinates; fourth, the possibility of losing the map and having to reconstruct another from the note-book references seems too remote to be considered (of course I know that maps have been lost)—as well have a topographer make two plane-table maps for fear one might be lost, or have all records made in duplicate because the note-book may be lost and therefore the

map made useless; fifth, many numbers must be used in the notes and therefore unnecessary figures should be eliminated.

As previously stated, most of the above suggestions are well known by working geologists and are presented as a record of personal methods rather than as new contributions.

PHILIP S. SMITH.

THE NATURE OF REPLACEMENT.

DISCUSSION OF PAPER BY W. LINDGREN.

Sir: I have been interested in reading Mr. Lindgren's article, "The Nature of Replacement," published in the September number of ECONOMIC GEOLOGY.

It may not be possible absolutely to contradict his statement that in "rigid rocks" the volume of replacing mineral equals the volume of mineral replaced. Nevertheless, I think it a duty to point out weaknesses in the evidence he brings as proof.

Among "rigid rocks" Mr. Lindgren includes limestones. Among examples of replacement in yielding substances he includes the formation of garnets in schists. In the former he says the law of equal volumes holds, but not in the latter.

In the experiments carried on at McGill University, on the yield of rocks, marble was chosen as an ideal yielding substance. It is safe to say that a fresh undecomposed schist, compressed in a direction perpendicular to the foliation, would not yield nearly so much as limestone or marble.

Schists, however, retain telltale lines of foliation, some of them consisting mainly of substances which are not replaceable under the conditions imposed. When a large crystal is being built up, these are pushed back and form curved, bulging lines which at once discount the probability of the law of equal volumes.

With limestone there is not such evidence. It can hardly be assumed, however, that the process of replacement is necessarily of an entirely different kind. The absence of cavities is nothing more than can be expected in any rock under metamorphic stress. Within a cavity the stress of the deformation would cease and

this stress is one of the main factors in metasomatism. This stress causes the solution of crystal faces perpendicular to it and the deposition of the same material on other faces. For example, with mica and other foliated minerals, material is dissolved from the tabular faces and deposited on the faces constituting the edges of the folia.

If a cavity should by any chance exist, the material immediately around it would be unduly stressed and would go into solution and be deposited again within the cavity. But there is no reason to presume that cavities are formed at great depths. As nature, on the surface, is said to abhor a vacuum, so, in deep seated rocks, nature may be said to abhor a cavity.

Among cavities are not to be included however those sub-capillary, perhaps sub-microscopic cleavages, joint and boundary planes along which solutions must circulate to some extent. Metasomatism cannot be explained except on the assumption that these exist. There are also good physical reasons why they can exist. Suppose the shells in a limestone, or the crystals in some other rock, are in the course of being replaced. Between the two there is no cavity but always a sub-capillary channel across which the replacement action goes on. Each particle is reproduced and any accidental porosity of the replaced material has its counterpart in the replacing material. The solution has not, however, necessarily satisfied its appetite for its new constituent. It does not take too much from the immediate vicinity of the replacement because that would cause a cavity. Instead it may take a little from the boundaries of all the sub-capillary channels for some distance around the actual displacement. The result would be a slight contraction of the whole rock mass which would not cause any understrain in any one place. It is not to be expected that this contraction would be evident in any subsequent microscopic examination. It does not follow that the contraction always occurs but neither does it follow that any law of equal volumes can be proved by microscopic evidence.

BLAMEY STEVENS.

REVIEWS

Ground Water and Springs; Underground Hydrogeology. By HANS HÖFER VON HEIMHALT. Frederich Vieweg and Son, Braunschweig, Germany, 1912. Price 4 Marks.

This volume of 135 pages of text liberally illustrated with 51 figures contains in convenient form discussions of features connected with the occurrence, source, and mineral content of ground waters. The causes and the distribution of rainfall, the permeability of rocks, the effects of natural features on supply of aquifers, and many similar topics are included. Methods of determining the ground-water plane and the rate of movement of ground waters are described together with observations on the influence of tide, pumping, and other factors on sub-surface supplies. Waters are classed as rock waters, springs, and mineral springs, the distinctions among the classes not being perfectly obvious. Nearly all phenomena regarding the appearance, mineral content, temperature, and fluctuations of wells and springs are noted and the conventional explanations of the various conditions not only are presented but are illustrated by numerous examples, principally European. The author's tendency is to carry classification into such detail as to confuse rather than enlighten the student.

His classification of mineral waters is interesting as it evidently represents the rating commonly accepted on the continent. He names and defines seven classes as follows, each of which is subdivided: (1) Carbonate (containing at least 1 gram per kilogram of bicarbonate); (2) halogen (containing salt in large quantity); (3) sulphate; (4) sulphur; (5) hydrochloric acid; (6) silicic acid; (7) radio-active.

R. B. DOLE.

The Iron Ores of Missouri. By G. W. CRANE. Vol. X., second series, Missouri Bureau of Geology and Mines, 1912, pp. 434, pl. 48, fig. 29.

Prior to the recent work by Mr. Crane, the most detailed investigation of the iron ores of Missouri was made by Mr. F. L. Nason, whose report was published in 1892. Due particularly to the later development of the limonite deposits in the southern half of the state and to a renewed

demand for information concerning the distribution and occurrence of the ores, this report has been prepared.

The iron bearing region, covering about 30,000 square miles, lies chiefly in the Ozark plateau. In this region four types of ore deposits are observed: (1) brown ores; (2) hematites of the filled sinks; (3) specular ores in porphyry; and (4) ores of the Silurian and Carboniferous formations. A chapter is devoted to each of these types of deposits, with special reference given to the origin of the ores.

1. The recent development of the primary and secondary limonites of southeastern and southwestern Missouri warrants particular attention in the report. These ores have been produced chiefly since 1900 and are believed to be equal in all respects to the limonites of the southern states. The reserves seem to be of sufficient importance to enable active mining operations to be carried on for many years at least.

The secondary deposits were derived directly through oxidation and hydration of the marcasite and pyrite originally deposited in the openings in the once overlying sandstones and limestones. The primary limonites were deposited as ferric hydrates in their present form either as bedded deposits or as fillings in cavities.

2. The "hematites of the filled sinks" referred to in previous reports as "specular ore in sandstones" are so called on account of the invariable association of the ores with a "filled sink" structure, differing in this respect as far as known from all other iron ore deposits in the United States. The "filled sinks" are formed by the solution of the dolomite beds, differing from the regular surface sinks in that the overlying sandstone bed instead of caving in, extends undisturbed across the cavity. The occurrence of this type of deposit is restricted to those areas in which the Roubidoux (Upper-Cambrian) sandstone is exposed. Future production will depend upon the discovery of new deposits as the properties now in operation are rapidly becoming exhausted.

It is believed that the iron was deposited within the filled sinks through the leaching of the sulphides and iron carbonates by meteoric waters in the overlying Pennsylvanian sediments, and that the iron was precipitated as sulphides in the sinks, becoming subsequently altered to its present composition.

3. Specular hematites directly associated with porphyry have been mined in relatively large commercial quantities as irregular veins and bedded deposits in the porphyry. These deposits are nearing exhaustion, although they have produced three fifths of the total iron ore production in the state. However, important reserves, which seem to consist chiefly of surface boulder and conglomerate ores, are available which will probably insure many years of active mining operations.

These ores are believed to have been deposited from hot iron-bearing

solutions coming from the porphyry itself as an after-effect of the intrusion. These ores are deposited as a replacement of the porphyry and as fissure fillings.

4. The hematite and carbonate ores of the Silurian and Carboniferous are at present unavailable and will probably never become of commercial importance.

The total production of iron ore in the state up to January 1, 1911, was 9,134,624 tons, of which the specular hematite in porphyry produced 61.61 per cent. The production of the hematites of the "filled sinks" was 33.64 per cent. and that of the brown ores was 3.19 per cent. However, in present production, the hematites in porphyry are the least important, producing in 1910 only 8.9 per cent. of the year's output. The hematites of the "filled sinks" lead with a production of 62.5 per cent. and the brown ores follow with a production of 28.6 per cent.

The latter half of the publication is devoted to concise descriptions of all the known deposits of iron ore in Missouri, embracing in all 642 properties.

Mr. Crane attributes the slow development of the iron ore industry in the past to inadequate transportation facilities, inadequate smelting facilities, and improper methods of mining. He is confident that improvement along these lines will be accompanied by a marked increase in ore production.

M. G. EDWARDS.

The Mining World Index of Current Literature. By GEORGE E. SISLEY. Vol. II., second half year 1912. Mining World Co., Chicago, 1913, pp. xx + 234. $2.00.

"Index" as used in the title of this book means a modified bibliography. To be most useful, a bibliography must contain a complete list of the literature of which it attempts to treat; it must have the articles listed in such a way that they may be readily found by reference to either authors or subjects, and it should state where the original article was published; where it has been reprinted or digested, if at all; its length; and a general idea of the contents. All these items of information except the last the Mining World "Index" supplies in an excellent manner.

The range of publications covered is very large, and it would be well if a list of the serials examined were given at the beginning of the volume. Such a list is of advantage to one who knows that such and such a periodical publishes much on certain subjects and who would like a definite statement that it has been indexed.

The range of subjects indexed would seem to include practically every-

thing published in journals and government publications in any way related to the mining industry. The subjects include such titles as "Cement-making and Working," "Transportation," "Stream Pollution," "Briquetting," "Filing and Indexing," "Mine Sanitation," "Schools and Societies," "Conservation" and "Syndicalism," which give a pleasing sense of good measure.

The division of the book into chapters with such headings as "Gold and Silver," "Coal," "Mines and Mining," "Mills and Milling," with many sub-heads, an index of authors and another of subjects makes the contents easily usable and easily findable.

Some mistakes have, of course, crept into the book. The reviewer can feelingly bear testimony to the nearly impossible task of so eliminating human fallibility as to prevent them. C. E. Siebenthal's article in "Mineral Resources of the United States," 1911, on zinc and cadmium is listed under "Cerium" and cadmium has escaped the index of subjects. A short article of the reviewer's on "Carnotite near Greenriver, Utah," is listed under "Tungsten" and an article by J. Gewecke, on thallium salts falls under "Tantalum and Niobium." And by the way it would be well to change this last word to the more correct "columbium."

In this day of the making of many books without end and the writing of too many articles, bibliographies are almost as necessary as dictionaries and the "Index" will be a useful tool to men in any way interested in the literature of economic geology, mining or metallurgy. It is to be hoped that some future volume may include short digests, if this does not increase the labor and cost of production beyond commercial feasibility.

FRANK L. HESS.

SCIENTIFIC NOTES AND NEWS[1]

ON SUNDAY, MAY 18, a serious fire destroyed a portion of the building of the United States Geological Survey, and many valuable documents and maps which were there on file This is the most serious fire that has yet occurred in a Geological Survey building, and it closes a series of similar accidents which have from time to time taken place in the wholly inadequate and unsafe structure in which the many valuable records are housed.

It would be difficult to estimate the loss to which the United States government is put by a fire of this kind; it vastly exceeds any immediate value which may be put upon the material destroyed. The labor and expense which these records represent in many cases have covered a long period of years and represent the expenditure of appropriations whose total would attain a very great size. In many cases the conditions under which the data were collected in mining districts have now so totally changed that none of the material on file can by any possibility be replaced.

That Congress should have ignored the repeated warnings which such fires have given is difficult to understand. The work which the Geological Survey is doing has, perhaps, been of more real value to the United States government than that of many more widely known and apparently important branches of the government service. It is to be hoped that no further delay in erecting a suitable place for keeping the material of the Survey and for increasing the efficiency of its work by allowing suitable space for those who are engaged in writing reports will take place, and that Congress will now realize that a comparatively small expenditure of money may be eventually a very wise and by no means insignificant economy.

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.

AT THE SOUTH AFRICAN School of Mines and Technology situated at Johannesburg, the council has made the following appointments to the staff:

Dr. G. S. Corstorphine, consulting geologist, to be principal of the school and professor of economic geology.

Mr. J. S. Cellier, mining engineer, to be professor of mining.

AT RECENT MEETINGS of the Geological Society of Washington, the following papers were presented:

April 23, "A Microscopic Study of Sulphide Ores of Copper," L. C. Graton.

May 14, "Geological Reconaissance Along the Lower Fraser River, B. C.," Norman L. Bowen. "Some Special Features of the Glaciation of the Catskill Mountains," H. E. Merwin. "The Present Attitude of German Geographers toward W. M. Davis' Explanatory Description of Land Forms," Francois E. Matthes.

A PAPER OF INTEREST to the readers of ECONOMIC GEOLOGY, presented at the April meeting of the Section of Geology and Mineralogy of the New York Academy of Sciences, was "Genesis of Certain Paleozoic Interbedded Iron Ores," by Raymond B. Earle. This paper was discussed on May 5. At the meeting of the Section of Biology held on May 12, W. D. Matthew read a paper on "Notes of a Visit to the Asphalt Fossil Beds near Los Angeles, California."

T. POOLE MAYNARD, Ph.D. (Johns Hopkins), 1909, mining and consulting geologist of Chattanooga, Tennessee, has been appointed consulting geologist with the Central of Georgia Railway. Dr. Maynard will study the mineral products now being developed along the Central and the undeveloped materials contiguous to the railway.

DURING THE FIRST TEN DAYS in May, Professor C. K. Leith, of the University of Wisconsin, conducted a group of twenty-five advanced students to the Lake Superior region to study pre-Cambrian geology and ores. The group was principally from the University of Wisconsin, but included graduates from Chicago, Minnesota, and other institutions. Dr. Per Geijer, of

Stockholm, a specialist on the geology of Swedish iron ores, accompanied the party.

E. H. CUNNINGHAM-CRAIG, of London, has in press a government report on the "Oil Possibilities of Barbadoes." Mr. Cunningham-Craig made a similar report for Trinidad.

PROFESSOR CHARLES E. VAN BARNEVELD, of the College of Mines, of the University of Minnesota, has been appointed director of the department of mines and metallurgy of the Panama-Pacific International Exposition, which will be held in San Francisco during 1915. The exhibit will include five groups:

1. Working of mines, ore beds, and stone quarries;
2. Mineral and stones and their utilization:
3. Mine models, maps, and photographs;
4. Metallurgy;
5. Literature of mining and metallurgy.

MESSRS. POILLON AND POIRIER, of New York, announce that they have opened an office at 63 Wall Street, and are prepared to examine and report on mines or mineral deposits and to take charge of operating properties.

MR. A. M. WALKER, of the topographic corps of the United States Geological Survey, gave a course of lectures on topographic mapping to advanced students in the department of geology of Northwestern University during the latter part of March and the early part of April.

UNDER THE DIRECTION of Mr. Eugene Haanel, director of the mines branch of the Department of Mines, Ottawa, an ore dressing and metallurgical laboratory has been erected for the purpose of conducting experimental concentration and metallurgical tests with Canadian ores and minerals.

MR. M. O. LEIGHTON, Chief Hydrographer of the U. S. Geological Survey, has resigned to enter the employ of J. G. White and Co., of New York.

MR. W. B. HEROY, of the U. S. Geological Survey, recently returned to Washington after three months absence in California.

MR. C. W. HAYES is visiting in Washington.

INTERNATIONAL ENGINEERING CONGRESS, 1915.—In connection with the Panama-Pacific International Exposition which will

be held in San Francisco in 1915, there will be an International Engineering Congress, in which engineers throughout the world will be invited to participate. The congress is to be conducted under the auspices of the following five national engineering societies: American Society of Civil Engineers, American Institute of Mining Engineers, American Society of Mechanical Engineers, American Institute of Electrical Engineers, and the Society of Naval Architects and Marine Engineers.

The committee has effected a permanent organization, with Professor William F. Durand as chairman, and W. A. Cattell as Secretary-Treasurer, and has established executive offices in the Foxcroft Building, 68 Post Street, San Francisco. The ten members of the committee, consisting of the presidents and secretaries of the five national societies, will constitute a committee on participation, through whom all invitations to take part in the congress will be issued to governments, engineering societies, and individuals.

The honorary officers of the congress will consist of a president and a number of vice-presidents, selected from among the most distinguished engineers of this and foreign countries.

The papers presented at the congress will be divided into groups or sections. During the congress each section will hold independent sessions, which will be presided over by a chairman eminent in the branches of engineering covered by his section. It is intended that the papers, discussions, and proceedings shall constitute an adequate review of the progress made during the past decade and an authoritative presentation of the latest developments and practices in the various branches of engineering work.

The papers will be collected and published by the congress, and should form a valuable engineering library. It is intended that this publication shall be in such form and at such cost as to become available to the greatest possible number.

The various committees are now actively at work, and it is hoped that further and more definite announcements as to the membership fees, schedules of papers, etc., can be made in the very near future.